

MAKER NATION

Popular Mechanics

HOW YOUR WORLD WORKS

SPECIAL
ISSUE

AMERICA
IS
BUILDING
AGAIN.
HOW YOU CAN
JOIN THE
REVOLUTION*

PAGE 64

Nick Wicks
Moreau,
a blacksmith
in Danbury,
Connecticut

EXCLUSIVE:
**Eddie
Van Halen,
GUITAR MAKER**
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HOW TO
SET UP
YOUR
ULTIMATE
HOME
WORKSHOP
(FLOOR PLAN INCLUDED!)

PAGE 90

GET
STARTED IN
WELDING

PAGE 47

BUILD A
TABLETOP
ROBOT

PAGE 111

*Or at least bone up on
your woodworking skills.

AMERICA'S
MAGAZINE
SINCE 1902

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Those are crushed oyster shells in the handle of the Edisto oyster knife made by Chris Williams on Johns Island, S.C.

ON THE COVER:

Blacksmith Nick Wicks Moreau of Wicks' Forge in his Danbury, Connecticut, workshop photographed for Popular Mechanics by Koury Angelo.

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LETTERS

CLOSED-DOOR NOSTALGIA

As I read Michael Pater-niti's story about Lego ("Everything Is Awesome and Mystical and Made Out of Plastic Bricks," April) and the boy behind the walnut door, I was flooded with memories of all of the characters and worlds that materialized when I used to turn those plastic bricks into an ever-changing story. Thank you for showing me the curiosity my parents must have had when I would go behind that door, a place one can only get to with a handful of Legos and an unchained imagination.

Anders Johnson
Glendale, California

YOU CAN'T PUT A PRICE ON THE SATISFACTION OF A JOB WELL DONE

In your tool-restoration story by Roy Berendsohn ("Project," March) you bought a gallon of white vinegar, steel wool, mineral spirits, rust-preventive primer, alkyd enamel, and a hickory handle. That's assuming you already had the sanding file, the punch, and the vise. How much time and money did you invest to salvage a hammer that you could've bought from a local hardware store? I see the effort for a \$600 table saw but for a \$20 hammer?

Eduardo Gonzalez
Mesquite, Texas

ON BRAS AND BABY ANKLES

Regarding how to un-snap a bra with one hand in your "Field Guide to Life" (April), there are some things that should be learned on a trial-and-error basis. Let's not reduce certain self-learned skills to a few drawings and written instructions.

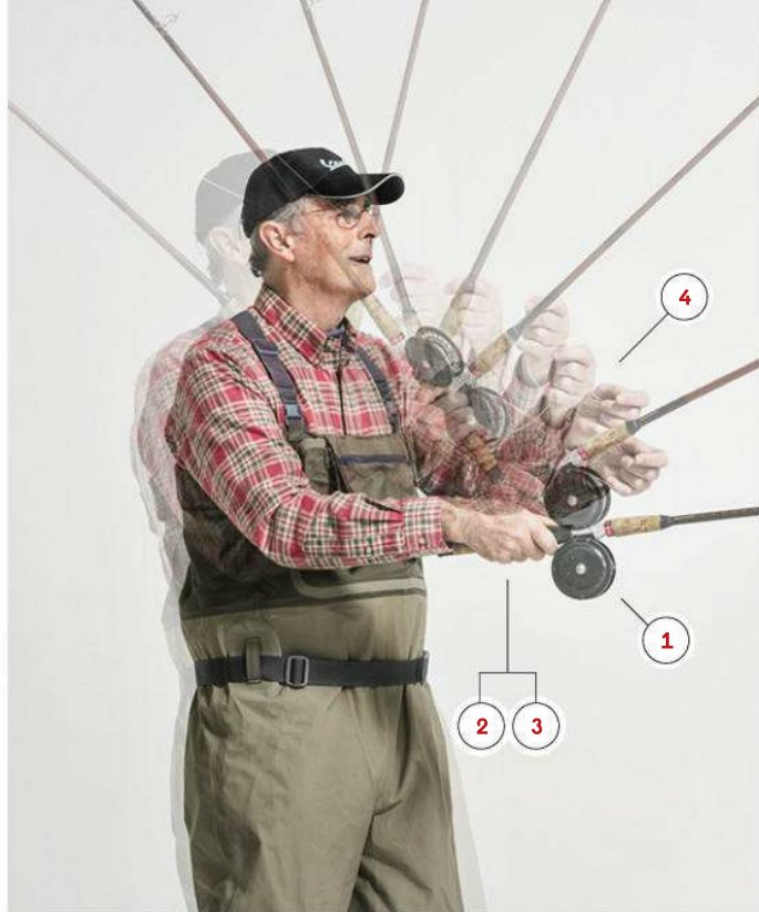
John McNichol
Altoona, Pennsylvania

The "Field Guide to Life" blew me away—"How to Unsnap a Bra With One Hand." You master that skill and your ego will breeze you through learning the others. Love is in the air. It's springtime!

Tom Sekula
Palmetto, Florida

Your piece about changing diapers is good. One note, though: In the third step, when holding both ankles with one hand, make sure that your index finger is between the baby's ankles so they are not rubbing together. Ankle bones knocking together can be painful for a baby.

Les Brockman
Salem, Oregon



CAN WE ASSUME THE GUY IN THE PHOTO WAS A BEGINNER?

I felt compelled to write that, as an IFFF [International Federation of Fly Fishers] certified fly-casting instructor, the photo accompanying "How to Fly Fish" ("The Popular Mechanics Field Guide to Life," April 2015) is wrong on so many levels (although I'm not taking this too terribly seriously).

- | | | | |
|---|---|---|---|
| 1
First off, the dude isn't even holding a fly rod. It's a spinning rod with a fly reel screwed into the reel seat. Oh, the horror! | 2
Secondly, he is holding the rod with his hand behind the reel, not in front. That simply cannot be! | 3
He is also using what is known as a V grip, which is a big no-no in fly casting. Thumb on top or index finger on top. Never the V grip. | 4
The photo shows the caster following the rod hand with his line hand, bringing it all the way up to his face. At this point I am breathing slowly into a brown-paper lunch bag so I don't pass out. |
|---|---|---|---|

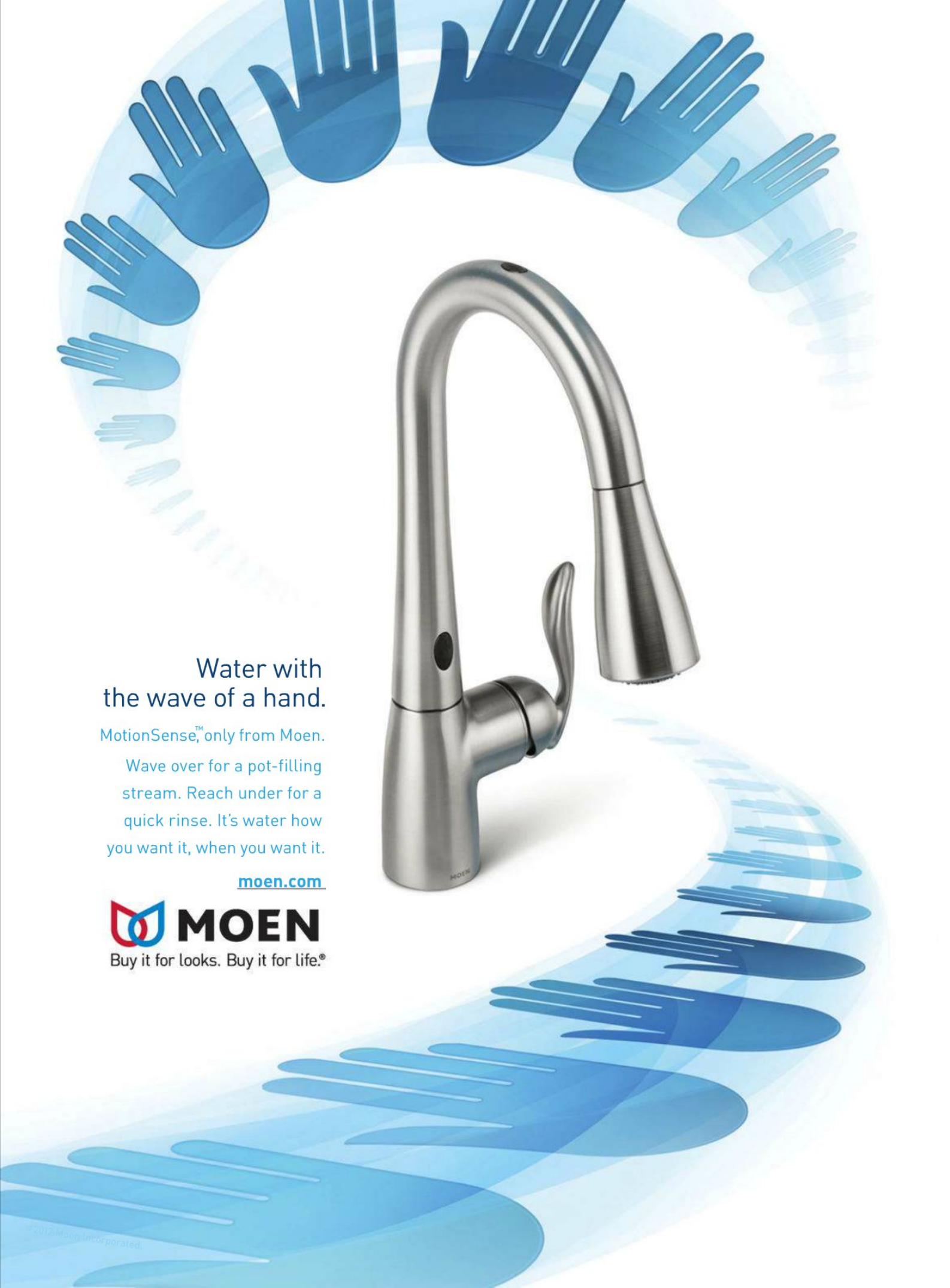


DAN BROWN

Taylors Falls, Minnesota

Thanks for being a good sport about our inferior technique. Our apologies to those anglers we left aghast. We'll be consulting Dan for all fly-fishing-related skills stories from here on out.

Letters to the editor can be emailed to editor@popularmechanics.com. Include your full name and address. Letters may be edited for length and clarity. **CUSTOMER SERVICE/SUBSCRIPTIONS online:** service.popularmechanics.com, **email:** popcustserv@cdsfulfillment.com, **mail:** Popular Mechanics, P.O. Box 6000, Harlan, IA 51593, **subscribe:** subscribe.popularmechanics.com.



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FROM THE EDITOR



Me and my dad sailing from Bermuda to Portland, Maine, in 2009. A bit of his boating wisdom: Keep your lines neatly coiled at all times.

WHAT I LEARNED FROM MY DAD

I think my truck has an exhaust leak. I know this is not a huge problem, but I also know it is one I have never fixed. The other day, over at my parents' house, I mentioned this to my father. He said, "Oh, sure," stepped into the garage, and from the top drawer of his red Craftsman tool chest he pulled a coaster-size tin of VersaChem Muffler Weld. First you find the leak, he said, by getting underneath while the truck is running and watching, smelling, and feeling for exhaust where it shouldn't be. Then you apply the Muffler Weld, wrap the wound in a scrap piece of sheet metal held in place with a couple of hose clamps, and you're good to go.

On one hand, this shouldn't have surprised me. My dad spent his youth fixing up cars for fun and plenty of weekends as an adult repairing cars out of necessity. Of course he knows how to fix a simple exhaust leak.

But on the other hand . . . *what?* You just have a tin of Muffler Weld handy at all times, right in the top drawer? Does everyone have this? How many exhaust leaks do your cars get? My dad works in an office every day. I see him all the time. I had no idea fixing exhaust leaks was a part of his life.

Everyone thinks their father knows everything. In my case, upon careful study, I have come to believe that for me, this is actually true. A few other things I have learned from him:

- When tying luggage to the roof of the car, you can never use enough rope or enough knots.
- Be home for dinner with your family. You can pick up the work again later, but that dinner is essential.
- With the right tool, you can do any job.
- If somebody lends you a car, return it with a full tank.
- It is acceptable to hire labor only for tasks you absolutely cannot perform yourself.
- Try to avoid borrowing cars.
- Work harder than anyone you know. Occasionally, take a great vacation.
- If it seems like you're getting a good deal, ask yourself why.
- Hey, don't throw that away. You never know when you might need it sometime.

I could fill every page in this magazine. But it's not like he sat me down one day and showed me a list of axioms and life lessons. He taught me (and my brother and sisters) by showing, by doing, by living. He's still showing us. That's how you teach anyone anything, from hammering a nail to being a good person. It's what my dad does for me, and it's what I'm trying to do for my own kids. Thanks, Dad. Happy Father's Day.

RYAN D'AGOSTINO
Editor in Chief



A BEAUTIFUL THING: In the photograph accompanying our fine piece of reporting on page 20 about the dangers of screen-related eyestrain, you'll see a handsome monitor stand by Grovemade. It's a gorgeous walnut piece made in Portland, Oregon. I just got one for my desk and it instantly made my workstation both more beautiful and more ergonomically sound. (\$119, grovemade.com)

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CALENDAR / JUNE

How to get the most out of your month.

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	1 Check your tire pressure. Keep them a couple of psi lower than recommended to compensate for the coming heat.	2 Stephen King's latest, <i>Finders Keepers</i> , comes out today.	3	4 Clean up the grill grates ahead of the weekend.	5	6 The seventy-first anniversary of D-day. Teach the kids a history lesson.
7 Caulk any cracks in your asphalt driveway before it gets too hot out.	8 Swing by the lumberyard and pick up the wood for the workbench project (page 99).	9 A band you didn't know you liked, Muse, releases its new album, <i>Drones</i> .			12 <i>Jurassic World</i> premieres. Chris Pratt and dinosaurs!	13 As good a time as any to get started on that workbench.
14 Watch Jimmie Johnson go for a repeat at Michigan International Speedway in the Nascar Quicken Loans 400 today.	15 	16 Between the new moon today and the full moon on July 1, it's prime time for good fishing.	17 If you've had a mix of rain and sun, do a pass of the mower at a higher height ahead of your regular weekend mow.	18 The PGA U.S. Open starts today. Great event to fall asleep to for a midafternoon nap.	19 Family movie night. Go see the latest from Pixar, <i>Inside Out</i> .	
21 Father's Day. If you're the old man, indulge your children's need to have a catch with you.	22 Yesterday officially kicked off summer. Make a gin rickey to celebrate.	23 Stream one of our new podcasts on your morning commute. Find them at popularmechanics.com/podcasts .	24 	25 It's really starting to warm up out there, huh?	26 Get the car washed.	
28 Find plans for the cabinet at popularmechanics.com/shaker-cabinet-plans . They're free!	29	30 Start planning an August road trip.				27 Use your new workbench to get started on making a Shaker wall cabinet (see page 88).

THU 4

HOW TO CLEAN GRILL GRATES

Scrape off large pieces of char, spray the grates with noncaustic oven cleaner, and keep them in a garbage bag overnight. The next morning scrub them with a brass brush and rinse clean.

MON 22

THE RELIABLE GIN RICKEY

Ingredients:

- Juice of half a lime
- 2 ounces gin
- Club soda

Into a Collins glass with ice, squeeze the juice of half a lime. Drop in the spent lime. Add the gin and top with club soda. That's it.

THU 25

WATER BETTER

As the weather warms up, keep your lawn from drying out by checking the moisture level of the soil and following our tips on how to water efficiently at popularmechanics.com/watertips.

TIP! MAKE YOUR CAR WINDSHIELD DEFINITELY SPOTLESS

As you saturate your windshield with water from a hose, scrub the windshield in small circular motions with 0000-grade superfine steel wool. [See page 74 for more things you can do with steel wool.] You'll know what has been cleaned and what spots you have missed by the way the water rolls off the surface. Follow up by applying a water repellent like Rain-X to the windshield and installing new wipers.

— Isaac Simmons Port Washington, New York

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FOUR MAKERS, FOUR LOGOS

We tasked four of the thirteen craftspeople featured in our “Maker Nation” story (see page 68) with reimagining the Popular Mechanics logo using their specialized skills and materials. The results were extraordinary.



1. NIAL MCGAUGHEY Radio and tube-amp paraphernalia

The “l” is a working guitar neck. We got the tuners all lined up and the strings to actually retain tension. It’s playable. I curated the parts and pieces, and roughly laid them out and had two of my guys help me with individual placement. It’s a jack-of-all-trades mix of skill sets here.

2. NICK WICKS MOREAU Steel and blacksmithing tools

I wanted to give a good representation of all the things you can do with metal, and incorporate some of the tools I use in metalworking. The stem of the “h” is a bending fork that’s used to bend metal. I used that same twisting fork to create the curved part of the “h.”

3. CHRIS WILLIAMS Electro-etched steel

This is similar to how we mark our own logo on our knives. We arced energy through the steel, removed the steel, turned it black, and put the blackened steel back on the stencil we’d removed. It’s all done by hand and with a little etching unit that I built from a bunch of RadioShack parts.

4. GRETA DE PARRY Screws in resin and wood

I wanted to make the logo so it didn’t look like it was done with CNC or laser cut. It’s simple to have something perfectly cut like that. At first you don’t know what you’re seeing. When you look harder, it’s like, whoa, that is a lot of screws. That can’t necessarily be done by a machine.

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GREAT NEW STUFF

The things you
need in your
life this month.



FILSON MACKINAW FIELD CHRONO WATCH FROM SHINOLA

Filson recently partnered with Detroit watchmaker Shinola to create its first-ever line of watches. The 43-millimeter Mackinaw has a long-lasting quartz movement, a chronograph, and a date function, and is rated to 660 feet. As perfect for a day of work as it is for a day on the lake. \$850



ADIDAS ADIPOWER BOOST GOLF SHOES

A golf version of the fantastically comfortable running shoe Adidas introduced a couple of years ago. Boost shoes have a bouncy, cushioned sole that supposedly returns energy to you as you run—and power as you swing. Who knows if that's what we were experiencing, but the fit was perfect, and the shoes felt rooted to the grass when we teed off. \$190



FISKARS POWERGEAR2 LOPPER

When Fiskars started making garden tools in 1985, the company revolutionized the industry. The PowerGear2 builds on that reputation (and on the original PowerGear) by adding beefier blade connections to prevent wobble. These loppers use a unique elliptical gear and hinge system instead of the traditional single pivot point for added torque. It makes cutting up to 2-inch limbs almost as easy as clipping a toenail. *Starting at \$29*



MAVEN B3 BINOCULARS

The Nike iD of midsize binoculars. After picking either 8x or 10x magnification, you can customize the color of everything, including the lens rings, the focus wheel, and even the logo. Engraving is an option, too, in case you care to sign your work. *Starting at \$500*

ORU BAY+ FOLDABLE KAYAK

An update on the company's original foldable kayak, the Bay+ has all the features of the Bay—watertight seams, a footrest, and, most important, the ability to fold up into something the size of an overstuffed suitcase, in case your home doesn't have space for a 12-foot boat—along with a new adjustable seat and ratcheting buckles. The Bay+ weighs 28 pounds and assembles in five minutes. After a little practice. \$1,495





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HOW YOUR WORLD WORKS

HOW TO WIN AN ARTILLERY WAR IN 2015

Russia's proxy army is inflicting heavy damage with rocket launchers in the new cold war. American drones, lasers, and other pioneering weaponry are helping Ukrainians fight back.

BY JOE PAPPALARDO

New technology has turned the old Russian BM-21 Grad, shown here in an artist's rendering, into a far more lethal piece of equipment.



The Ukrainian army's 24th Mechanized Brigade had just passed through the village of Zelenopil'ya at 4 a.m. last July when the sky detonated. Dozens of 122-millimeter rockets fell on the convoy in an area claimed by Russian-backed separatists, each rocket carrying about fifty pounds of explosives in warheads built to fragment into shrapnel. Within moments nineteen soldiers lay dead and scores more wounded. Vehicles were shredded. The rebels likely used a BM-21 Grad, a six-wheeled vehicle with forty launch tubes that can all fire within seconds (*grad* means hail in Russian).



THIS MONTH IN

Putin

The Guardian revealed that Russia hires bloggers to, among other things, criticize Ukraine, praise Putin, and promote Russia's top-selling YotaPhone.

These attacks haunt Ukrainian troops: A Brookings Institution field report said the bombardments account for 70 percent of their casualties. In fact, multiple-launch rocket systems (MLRS) are now so common that more than eighty nations, including Syria and Iran, deploy them. So do terrorist and other nonstate

Middle Eastern groups. MLRS operators can park and launch within two minutes, then quickly relocate to a bunker, under a camouflage net, or inside a cave—the tactic is called shoot and scoot.

And they don't fire blind. In Ukraine, Russian drones with video cameras provide separatists with valuable information. Ukrainian soldiers have told reporters that they often see the drones overhead before an MLRS bombardment but have no way to shoot them down. The Brookings researchers reported that the Russians deploy UAVs (unmanned aerial vehicles) and artillery in tandem "with devastating effect." In response, the U.S. military is ramping up its own technology to help its ally fight back. Here are four prime examples:



AIR-DEFENSE LASERS

In 2014 the Navy's first laser weapon—a warship turret that can crisp small boats and UAVs—became operational. The hundred-kilowatt system, now deployed in the Persian Gulf, burned a hole through a drone in seconds during target practice. Next the Navy wants more compact, stable, and rugged weapons that can shoot drones from Humvees. The Office of Naval Research announced an industrial contest to create laser weapons that can do the same with just twenty-five kilowatts. Demonstrations are expected in 2016.



PORTABLE AIR-DEFENSE RADAR

Once it's possible to hit the UAVs with lasers, the military will be able to locate them using mobile warning radar. Active electronically scanned arrays (AESA), which can easily be carried in vehicles and set up on tripods, send out pencil-thin radar beams with jolts of current that scan the sky for drones. Some U.S. versions can detect, classify, and track any kind of airborne object at altitudes ranging from thirty feet to 30,000, and have ranges of up to eighteen miles.



MLRS-TARGETING TECHNOLOGY

The modern battlefield is blanketed with sensors—mobile ground radar, acoustic surveillance equipment at observation posts, satellite imagery, and infrared camera feeds from drones—that can be used to help find MLRS locations. Last year the Marine Corps began developing software to identify an incoming threat using all data, then plot the exact location for return fire—which could "compress the kill chain timeline," says one military document.



MEDIUM-RANGE UAVS

Drones that can travel beyond an operator's line of sight are ideal tools to pinpoint mobile artillery. The MQ-5B Hunter can fly at 18,000 feet, high enough to avoid most ground fire. It is capable of both scanning the terrain below with an array of cameras (including infrared) and intercepting signals from enemy communications. The MQ-5B can stay in the air for twenty-one hours, beaming back real-time information for counterattacks.

how do i

how do i get a girlfriend
how do i fix my DVR
how do i take a screen shot
how do i renew a passport
how do i make dinner
how do i train my dog
how do i catch a terrorist

A SEARCH ENGINE TO STOP ISIS

There's a scary Internet that most of us have never seen. It's called the Darknet—a free-for-all marketplace of drugs, sex, guns, and everything else your parents warned you about. Darknet sites won't show up on Google, but they will show up on Memex, a new search engine designed by DARPA that reaches every corner of the Web. Originally created to combat human trafficking, Memex is now used to fight the Islamic State group. Many ISIS supporters use Darknet to funnel money, often bitcoin, to terrorist cells. Memex searches, indexes, and cross-references forums, advertisements, and chats, identifying patterns that point law enforcement to the payment sources—where ideally they can be stopped. — CAMERON JOHNSON

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WARNING: This product contains nicotine derived from tobacco. Nicotine is an addictive chemical. (Photography by Francesco Carrozzini)



HOW DIPPIN' DOTS ARE MADE

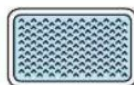
- **Step 1:** At the production facility in Paducah, Ky., dairy mix and flavoring travel through 1.5 miles of piping to one of five cryogenic processors.
- **Step 2:** In the processors the mix rains into a minus 320 F pool, flash-freezing into 4-millimeter spheres.

Relative ice-crystal size in slow versus fast freezing



REGULAR FREEZING

Water droplets cluster while crystallizing, breaking cell walls.



FLASH FREEZING

Smaller, more numerous crystals form before water can move.

eliminate the grueling task of shucking. Second, a soup made of frozen peas will be substantially sweeter and better tasting than a soup made of fresh peas. Fergus Henderson, the chef of St. John in London, said it best: "Wait until peas are in season. Then use frozen."

Is there a downside to freezing? Sure. That's where the reputation comes from. When a food gets extremely cold, what is really freezing is the water within it, which expands and forms crystals that can tear at the food's structure. Done improperly or to the wrong food, this can destroy both taste and texture: You can't, for example, freeze corn on its cob—you'd

have to cook it that way, then present your texturally weird, freezer-burned corncobs to your dinner guests.

There are, however, foods that are improved by the freezing process. Peas are one of them. (Another, surprisingly, is octopus.) In fact, many frozen fruits and vegetables taste as good as or better than their fresh counterparts. All fruits and vegetables start to degrade the minute they leave the field: Enzymes convert the sugars into starches, and the light, heat, and handling that go into moving a crop from field to market inevitably damage it. Because frozen foods are picked at the peak of ripeness, then blanched and frozen, they stay as tasty as they'd be if you had eaten them in the farmhouse next to the field where they grew. This is why Birds Eye famously promises two and a half hours from field to freezer. And according to studies done at the University of California, Davis, and the University of Georgia, because freezing stops fruits and vegetables from breaking down, frozen foods are often higher in nutrients than fresh ones.

Even at ages 2 and 5, my kids see the value in the extremely sweet fruit that comes from the freezer. The younger one eats frozen blueberries by the bowlful (I prefer these to fresh ones flown in from another country), and both of them are amazed by the creamy texture and profound sweetness of frozen bananas. When I dice up some of the latter and stir them into an otherwise boring bowl of oatmeal, I'm magically a good dad: I'm getting fiber and vitamins into my daughter, and, for once, she thinks I'm a decent cook.

— With thanks to Syed Rizvi, professor of food process engineering at Cornell University.

IN DEFENSE OF FROZEN FOOD

When it comes to fruits and vegetables, the freezer just might be the most underrated tool in your kitchen.

BY WYLIE DUFRESNE

IN ONE OF MY RESTAURANTS, a cook once came up to me and announced in disgust that he couldn't possibly work in a kitchen that used frozen peas. It didn't bother me that he had challenged my authority. It did bother me that he was dead wrong about frozen peas. Many people think of frozen food as a cheap shortcut, a last resort. All of them need to get off their high horse and make a batch of pea soup, immediately.

Almost every good cook's epiphany about frozen food comes while making pea soup. First, frozen peas

Our columnist takes a break from eating all the bananas in his restaurant's freezer.



FLASH-FREEZE YOUR SUMMER PRODUCE

If you have \$1,235 to spare for a really fun toy, you can buy a PolyScience Anti-Griddle, which has a minus 29.2 degree Fahrenheit surface that will flash-freeze almost anything. If you don't, chop your produce into small pieces. Blanch vegetables for several minutes in boiling water, then dry. Fruit is fine as is. Spread produce on a cookie sheet in a cooler full of food-grade dry ice. Once the produce is frozen, you can bag it up and transfer to the freezer.

MOEN INSPIRED

Moen's kitchen faucets with Reflex™ technology work the way they're supposed to: the spray head self-retracts fully and puts itself away securely. See how four makers were inspired by Reflex to create other inventions that put themselves away. #InspiredByReflex



SIPPY CUP HOLDER



SELF-RETURNING SHOPPING CARTS



1. The duo behind the first-of-its-kind invention 2. The concept was white-boarded to construct a framework 3. The structure was customized with a circular saw 4. GPS helps the cart find the best route to the return



Developers John McClaire and David Vogeeler admitted to leaving their grocery shopping carts strewn about in parking lots. Then they realized, if the Moen faucet could put itself away, their carts could, too. With just two simple motors and a battery, the prototype showed promise. Then GPS was added in order to allow the cart to make decisions based on moving objects. "I think people are going to ask, 'Why hasn't this happened sooner?'" says John.



1. Materials include a recoiling mechanism and plastic holder 2. Originally conceived to mimic the Moen faucet's Reflex feature 3. Prototype keeps the sippy cup in place

Father of three Mike Kelley had a problem: getting his daughter's thrown sippy cup back on her high-chair table. Inspiration struck when he saw how his Moen faucet goes back to where it belongs via the Reflex feature. Kelley used a micro recoiling system and self-manufactured a 3D-printed plastic cup holder. "The real test was when I put Harper in the chair. I think my invention was a success," proudly declares Kelley.

When mechanical engineering student Leo Prinzi saw the Moen faucet's Reflex technology, he had a thought: What if other things could put themselves away, too—like toys? He began by sketching and laser-cutting cardboard prototype parts, and then assembling an acrylic machine with a sensor inside. With it, the bot could detect a toy and grab it. "I definitely think it was a success ... after this, moms owe me a lot of cookies!" exclaims Prinzi.

1. Strategically placing a sensor inside the bot 2. The Moen faucet Reflex feature inspired the system 3. The successful prototype automatically cleaning up toys

TOY BOT RETRACTOR



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The colors you see, sorted by wavelength.

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Harsh, short-wave-length light from phones and tablets

600 nanometers and up

Candlelight and dark-room light: minimal effect on sleep patterns

540-560 nanometers

Peak intensity for a typical fluorescent bulb

BEWARE THE LIGHT

Most people stare at screens at least eight hours a day. This is not a good thing. **BY ALEXANDER GEORGE**

MY OBSESSION WITH EYESTRAIN started in junior high. Within a year of getting my first laptop, I had to be fitted for my first pair of glasses. From then on I did everything I could to keep my eyes from getting worse. Originally that meant turning my monitor brightness way down and taking frequent breaks from the screen. But in the years since, as research pours in showing that our constant exposure to artificial light may lead to everything from insomnia to obesity to prostate cancer, I've had to up my vigilance. Which meant incorporating some potentially embarrassing equipment to protect myself. Forget vanity. I needed a solution—one that didn't involve spending any time away from my phone.

F.lux, free

Type in your time zone and as the sun sets, f.lux slowly turns the harsh blues and whites on your screen to candle-like yellows and browns. Your brain confuses blue light for daylight, affecting your circadian rhythm and suppressing your body's natural sleep agent, melatonin. Richard Stevens, a professor of community medicine and health-care at the University of Connecticut, says that "after dusk, you want light that's as dim and red as is comfortable."

Gunnar Haus glasses, \$99

The tinted lenses reduce high-energy blue light that, according to Ron Adelman of the department of ophthalmology and visual science at Yale, tires out your eyes. And the glasses' antireflective coating helps with glare from overhead lighting, which, Adelman says, "reduces your eyes' sensitivity, forcing them to work harder to see details."

Philips Hue Go, \$100

To combat morning grogginess, I set the color-adjustable Hue lightbulb to fill my bedroom with blue-rich white light. Carrying it around during my morning routine has replaced the industrial-size coffee I used to need. At night, I set Hue Go to a deep red. Aircraft carriers often use red lights in sleeping quarters to illuminate a space without jolting your brain awake.

Moleskine Evernote Weekly Planner, \$35

Besides giving your eyes a break from glowing screens, writing by hand results in greater comprehension. With Moleskine's Evernote technology, you write a note, then take a picture of the page with your phone. The app uses the page's dots to decipher the ink, turning your handwriting into searchable text. I've had to learn to write more legibly, but I needed to do that anyway.

Orange

Lots of vitamin C. Good for the eyes.



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WORLD
WORKS

GREAT
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Q

WHY DO SCI-FI WRITERS ALWAYS SEEM TO OVERESTIMATE HOW MUCH THE WORLD WILL HAVE CHANGED BY THE YEAR THEY'RE WRITING ABOUT?

A IT'S NOT JUST science-fiction writers. If you'd asked me in high school what I'd be doing right now, the answer would have involved far more hot-tubbing with Icelandic supermodels and far less answering questions in magazine columns. We all have fantasies, in other words, and few of us, whether we're sci-fi writers or hardware-store managers, see them come true in every particular.

But let's look specifically at the sci-fi genre: While every writer has his or her own process, a common creative approach is to identify a trend in science, society, or, ideally, both, and project it some distance into the future. The author must decide: What will the world look like, and when will it look that way?

Consider now that the sci-fi writer must devise a story and a setting people will find interesting—assuming he wishes to avoid a second career answering questions in magazines. Here he faces a catch-22. If the imagined world is too similar to contemporary reality, it may be insufficiently exotic to capture a reader's interest. On the other hand, if the story is set too far in the future—2,000 years, say—it risks feeling too remote to care about. These twin imperatives dictate that writers pack the maximum social and/or scientific change

into the minimum plausible time span. The inevitable result is the almost universal tendency for “predictions” made in science fiction to fail to come true on time, if at all. Remember, though: Sci-fi writers are seldom attempting to predict the future so much as they're trying to provoke thought by asking, What if? So cut 'em a break. You want Nostradamus, read Nostradamus.

How often do busy gas stations need a refill?

The average gas station dispenses between 3,000 and 4,000 gallons a day. A typical station's underground tanks (usually two*—one for regular, one for premium) hold 8,000 to 12,000 gallons total, which, according to the liquid-cooled supercomputer this magazine leases from NASA, means they require a delivery every . . . every . . . ding!—two to four days. An extremely busy station, on the perfect corner in Jersey, maybe, or associated with a big-box discount store such as Costco, might need to fill 'er up once or even twice a day. Truck stops, though, are in a class by themselves. They can require refills as often as five times daily, and might pump as much as 1,000,000 gallons of gas a month, along with, one suspects, a similar amount of bad coffee.

Do you have unusual questions about how things work and why stuff happens? This is the place to ask them. Don't be afraid. Nobody will laugh at you here. Email greatunknowns@popularmechanics.com. Questions will be selected based on quality or at our whim.

Of all the homes ever built in the U.S., what vintage are the best built? Are there in fact better or worse decades for home construction?

Are you selling your home? If so, tell buyers it was built in the best decade for home construction. That new house you're bidding on? Built in the worst decade. They're lucky you're willing to cross the threshold without a hard hat, let alone make an offer. Or so you might reasonably claim, because the truth is there is no single best period for home building, nor is there a worst. Every era has its pluses and minuses, and the skill and care of the builder can be every bit as important as when a home was built.

That said, homes built in the late nineteenth and early twentieth centuries have held up remarkably well, due largely to superior framing materials. Back then builders had access to plenty of old-growth lumber, which is considerably harder than the wood used today. This not only dissuades termites, who tire of breaking their teeth (or whatever the dickens they have) on tough-as-titanium 2 x 4s, but also limits water damage, as the denser wood is less absorbent. On the downside, though, homes of this vintage were constructed by a method known as balloon framing, in which a single long stud might extend from the first floor to the attic. This lets fire spread far more easily than does the platform framing used since World War II. Moreover, later poured-concrete foundations are much more stable than the stone and/or brick ones in these older houses.

Other era-specific gotchas include corrosion-prone galvanized plumbing used in the 1950s, aluminum wiring—a potential fire hazard—popular in the late sixties and early seventies, interior moisture problems (think rot and mold) that came with increased insulation and insufficient ventilation in the 1980s, problems with furnace venting in the nineties, and toxic Chinese drywall in the 2000s. Not every home will have these particular problems, of course, and many fine dwellings have been built every year since man discovered fire and his wife discovered draperies. To be safe, though, picky buyers may do best to find a modest medieval castle in a good school district. It'll be fireproof, well-ventilated, impervious to insects—and who needs a security system when you've got giant vats of boiling oil? Just be sure to check the dungeon for signs of flooding from the moat.

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SKILLS

Bowers & Wilkins CM Series Speakers, from \$700

A good frequency response (which frequencies the speaker can play) for a center speaker is 70 to 22,000 hertz. An ideal sensitivity (how loud it can play on one watt) is about 87 decibels. The Centre S2 (shown) can go from 70 to 28,000 hertz with a sensitivity of 87 decibels.

Marantz UD5007 Universal Disc Player, \$599

A high-end record player and pristine records will give you great sound, but according to our expert, audio-video consultant Mike Olson at Park Avenue Audio, CDs are more reliable. And if you want to watch movies, a disc player is an integral part of the setup.

THE AUDIOPHILE'S GUIDE TO HIGH- FIDELITY SOUND

In 2015 music is maximally portable. You can take the same playlist to the gym, the beach, your car, and your office. But your house is still your kingdom. Here's how to make whatever you listen to sound best where it counts.

BY MATT GOULET

Sonos Connect, \$349

Wirelessly integrates anything on your computer or mobile device, as well as pre-loaded radio stations and online services, into your sound system. It can broadcast lossless files (which don't delete information during the compression process) to multiple rooms, and can even send sound wirelessly to some speakers.

Marantz SR6009 Net- work A/V Receiver, \$1,299

A receiver like this one processes any type of input you can think of—that record or Blu-ray player, cassettes, even HDMI inputs—and converts it into an analog signal that will drive the sound through your speakers. This one can also stream music, like the Sonos Connect.

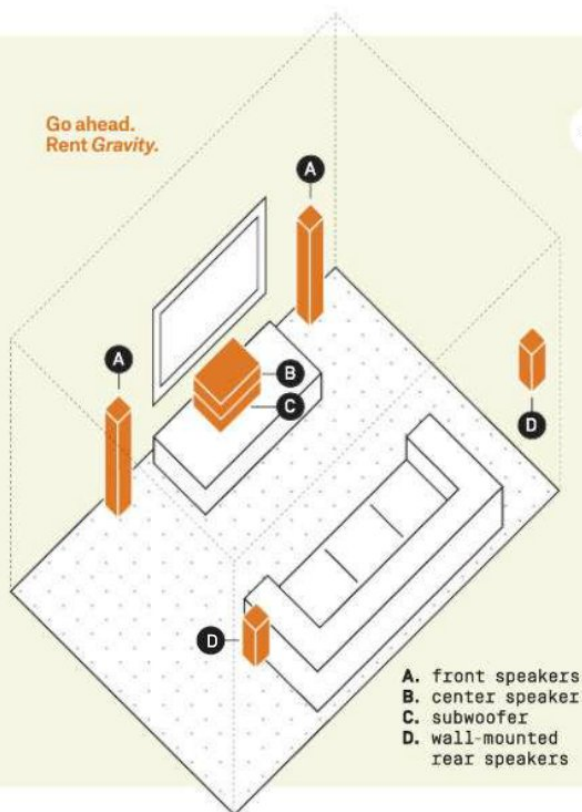
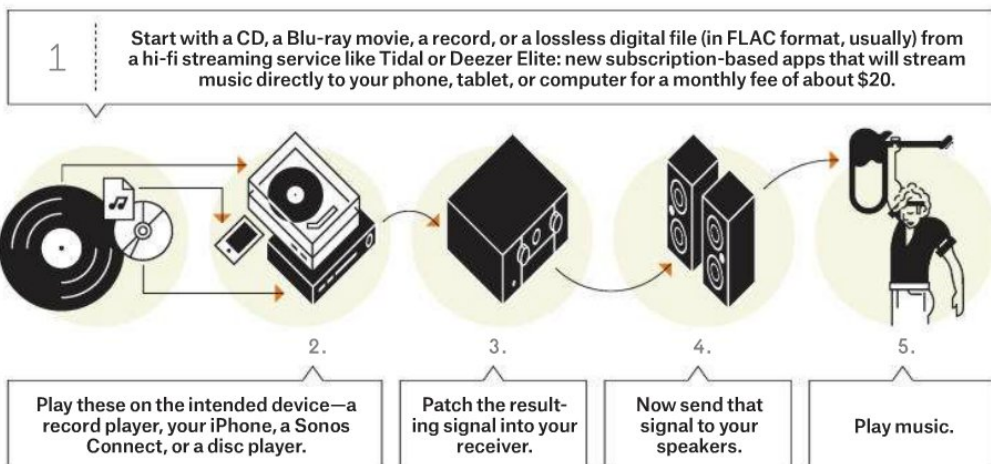


SKILLS

SOUND

THE ULTIMATE SYSTEM

If any part of your audio setup doesn't operate at hi-fi capacity, from the source file to the speakers, you can end up with distorted sound with the high and low ends lopped off. Whole bass lines can disappear. This is especially important for complicated, layered jazz, rock, and classical music, as well as for movies with overlapping effects and dialogue. To get the enveloping, detailed sound you'd hear if you were watching at a theater or listening to a band live, you need a system like this.



SO YOU WANT TO WATCH MOVIES

To play both music and movies, you need a 5.1-channel setup. That's five speakers, with a subwoofer acting as the bonus .1. Unless it's mixed for 5.1, your music will play on only two channels—your two largest speakers, plus the subwoofer. Movies incorporate complete surround sound, which includes two rear speakers and the center speaker. The center will play a dedicated dialogue channel, so you can hear what characters are saying over loud background music or action-related cacophony.

Assuming your TV sits in the center of a wall, you want your biggest speakers on either side of the entertainment center. Place a center speaker console and the subwoofer under the TV. Place the rear speakers just behind you at ear level—about 32 inches when sitting—and parallel to the front side speakers. You can also mount these and point them downward. Now put in a movie on Blu-ray. The more explosions, the better.

HOW TO SHOP • You wouldn't buy a mattress on the Web without testing it in a store first, would you? Give your sound system the same respect. Bring a couple of your favorite CDs to play. And take note of the listening room's acoustics. Most hi-fi stores are carpeted and absorb sound. If your room at home is all hardwood and bare walls, expect the speakers to sound significantly louder and more open there. (Also, maybe buy some art.)

COMMUNITY AUDIO



10 EXCELLENT HI-FI STORES

Community Audio
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Does home installations.

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Most of the staff have more than 20 years of experience.

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Urbandale, Iowa
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Q Audio
Cambridge, Mass.
Has been selling new and used equipment to MIT students since 1981.

Tune: Hi-Fi for Humans
Seattle
Offers demonstrations by appointment.

3mA Audio
Houston
Founded by three collectors, but sells both vintage and new equipment.

Echo Audio
Portland, Ore.
Posts stock online so you can browse from your couch.

Music Lovers Audio
Berkeley/San Francisco, Calif.
Both Bay Area outposts host regular events to show off new equipment.

Audio Advice
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Call ahead and the staff will set up a system for you in a demonstration room.

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THE KIDS IN THE GARAGE

How to strip, repair, repaint, and rewire an old car—with help from an after-school auto club. Part five of a six-month series.

THE FIRST TIME Mike Vanderheiden, a 17-year-old junior at Freedom High School in Freedom, Wisconsin, disassembled a drum brake, he was 10, and it took him the whole day to put it back together. “As soon as I pulled off the drum, everything fell apart on me,” he says. These days Vanderheiden’s a pro, repairing trucks for his dad’s business as a part-time job. His knowledge also comes in handy around Freedom High’s garage, where he helps fellow students with less experience work on the drum brakes for the club’s nearly complete 1974 Oldsmobile Delta 88 and 1981 Chevrolet Camaro Z28 project cars. Today Vanderheiden can reassemble a brake in just 20 minutes, which he learned with the help of a smart trick: taking a picture first.

Junior Mike Vanderheiden uses skills he learned in his dad’s shop to remove the Camaro’s drum brakes.



CAR SHOPPING WITH AN AUTO INSTRUCTOR When I was a kid my dad used to make me scrub the wheels on our beaters that we drove to races he worked. My job was to clean each wheel to get rid of brake dust. That stuff is just terrible. When I talk to kids about buying cars, it’s one of the things I talk about. Semimetallic pads leave an ugly black dust that stains and damages the wheel’s finish. If I see this on a car I’m considering, it’s a deal breaker. It’s a sign of poor care. When it comes to something as important as braking, you want the best. — JAY ABITZ

HOW TO

REPLACE A DISC BRAKE PAD

Tips from the Freedom High School Automotive Program

Though most modern cars come with disc brakes, the Oldsmobile and the Chevrolet also have drum brakes. Freedom High’s auto club works on both, so we asked them how to replace a disc pad.

STEP ONE

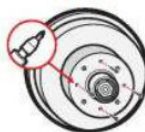
Remove the brake caliper.



With the car elevated and the wheel off, remove the brake caliper by taking out the caliper bolts with a socket wrench. Do not let the caliper hang freely or it could damage the connected brake line. Set the caliper on a raised surface instead.

STEP TWO

Replace the rotor.



When changing brake pads, you must either machine the rotors smooth or completely replace them to prevent them from unevenly wearing the new pads. Rotors aren’t very expensive these days, so it’s usually wise just to buy new ones.

STEP THREE

Compress the piston.



The piston is the part of the caliper that applies the hydraulic pressure that presses the pads against the rotor, halting the wheels. Braking causes the piston to stick out slightly, so you’ll need to compress the piston back into the caliper. With the old inner pad still in place, use a C-clamp to do this.

STEP FOUR

Reassemble the brake.



Snap your two new pads on both sides of the caliper and slide it back into position over the rotor. Then use a torque wrench to secure the caliper bolts to the manufacturer’s torque specification, which can be found in your car’s manual. Your local parts supplier would know, too, if the manual’s gone missing. (Abitz recommends O’Reilly Auto Parts.)



NEXT MONTH

Fuel Line Repair

Dupli-Color® Scratch Fix All-in-1™

The ultimate tool for vehicle scratch and chip repair.

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1. Prep it.

Abrasive tip removes loose paint & rust.



2. Paint it.

Pen tip for fine scratches.



Brush end for larger chips.



3. Seal it.

Clear coat to seal, protect & ensure a perfect factory matched finish.



SKILLS

THINGS COME APART

A PHOTOGRAPH BY
TODD McLELLAN



DISASSEMBLY REPORT: BLENDER

MODEL: WARING PBB212

PRODUCED:
McCONNELLSBURG, PA.

DISASSEMBLED:
TORONTO

NOTES:

Fred Waring was a big band conductor whose band, Fred Waring's Pennsylvanians, was the first to electronically record a song. When an inventor approached Waring to invest in his early blender, the Miracle Mixer, Waring tweaked and renamed the product. The Waring Blender debuted in 1937. Odd spelling aside, it looked pretty much like what you see here.

NUMBER
OF PARTS:

87

TIME TO
DISASSEMBLE:
1 HOUR,
12 MINUTES,
2 SECONDS

- 1 **DRIVE COUPLING:** The mechanical linkage between the motor and the blade. Made of die-cast zinc.
- 2 **BAFFLE:** The fan pulls air in through the bottom of the base, cooling the motor. The baffle ensures that the heated air flows out the top of the base instead of recirculating around the hot parts.
- 3 **BLADE:** Not ordinarily removable, it's designed to last for at least 100 hours of continuous blending.
- 4 **BASE PLATE:** The five holes in the center are for air intake.
- 5 **END-BELL BRACKET:** Holds the motor in a vertical orientation below the blade.
- 6 **UNIVERSAL MOTOR:** Can operate on either AC or DC power. On the blender's HI setting, the motor operates on 120 volts AC. On LO the voltage is rectified down to 90 volts DC to decrease the speed of the blade.
- 7 **LID:** Made of a soft vinyl that forms a tight seal.
- 8 **JAR:** This is where the food goes, but you probably guessed that. The cloverleaf shape disrupts the vortex that forms in the blender to promote more comprehensive mixing. This jar is made of silica glass, which can handle a 180 degree Fahrenheit temperature change.
- 9 **BLADE-ASSEMBLY GASKETS:** Made of Teflon to absorb impact from disorderly foodstuffs.
- 10 **NAMEPLATE:** Stamped metal that's riveted in place, the way it's always been.
- 11 **BASE:** This is made of electrostatically powder-coated, die-cast zinc, which keeps high-frequency motor sounds from annoying the dog.
- 12 **JAR-PAD STUDS:** These fasteners are inserted, pointy side down, into the entire base assembly, and bolted to the end-bell bracket to hold everything together. Then the red pads go on the wide ends to stabilize the jar.

— KEVIN DUPZYK

HOW TO MAKE AN UNEMBARRASSING BLENDER DRINK

If it's hot enough outside for ice cream, it's hot enough for a frozen beverage. But no one wants to be caught at the backyard barbecue drinking something pink and frothy out of a coconut. Yael Vengroff, beverage director of The Spare Room, the bar at The Hollywood Roosevelt hotel, suggests making a Kentucky Maid, a riff on the mint julep, instead. "Frozen whiskey drinks are rad," she says. "And it's green, so it's not a girly color."

THE KENTUCKY MAID

➔ To make, mix 1.5 ounces high-proof bourbon, such as Old Grand-Dad, with 1 ounce demerara simple syrup (two parts demerara sugar and one part water heated on low until the sugar

dissolves), ¾ ounce fresh lime juice, six to eight mint leaves, three cucumber slices, and about a cup of ice, and blend until smooth. Garnish by poking a small mint sprig through a slice of cucumber.

THE NEW, IMPROVED IMPACT WRENCH

Competition among these battery-powered tools is so tight, we almost couldn't pick a winner.

BY ROY BERENDSOHN and JOSEPH TRUINI

Over the past two decades we've tested hundreds of tools, but we never ran a competition this close. First, we tightened $\frac{3}{8}$ -inch and $\frac{1}{2}$ -inch nuts with a torque wrench. Then we gathered seven cordless impact wrenches and removed the nuts. Somehow there wasn't a single tool with which we had a substantial complaint. We even tried it blindfolded, and could barely differentiate among our top performers. We chose our winner based on subjective measures: how it handled, balance, and grip. In terms of pure performance, though, the 4½-star machines are just as good. Tools have come a long way in twenty years.



★★★★★

DEWALT
DCF899P1 \$349

Volts: 20

Amp-hours: 5

$\frac{3}{4}$ -inch nut:

0.5 second

Likes: This enormous brute of a tool comes with three speed-limit settings of 400, 1,200, and 1,900 revolutions per minute, which provide control even when you can't see what you're doing. Despite its industrial-duty motor, it's agile and easy to use, thanks to a slim handle and unfussy design.

BEST
OVERALL



BOSCH IWBH182-01L \$300

★★★★★

Volts: 18

Amp-hours: 4

$\frac{3}{4}$ -inch nut: 2.99 seconds

Likes: Of the three compact tools in this test, this one had the most power and was very quick on the draw, due to an extremely slim handle and good weight distribution.



CRAFTSMAN ID2030K \$160

★★★★★

Volts: 19.2

Amp-hours: 4

$\frac{3}{4}$ -inch nut: 2.98 seconds

Likes: First, you get a lot of tool for your money. Second, the handle has a textured, nonslip rubber overmold, so you won't lose your grip, no matter how greasy your hands are.



MILWAUKEE 2763-22 \$430

★★★★★

Volts: 18

Amp-hours: 4

$\frac{3}{4}$ -inch nut: 0.5 second

Likes: Milwaukee's tools perform well, test in and test out. This is no exception. And when the going gets tough, you can push from behind the motor housing for extra oomph.



INGERSOLL RAND W7150-K2 \$430

★★★★★

Volts: 20

Amp-hours: 3

$\frac{3}{4}$ -inch nut: 0.5 second

Likes: Ingersoll Rand was building air wrenches decades before other companies even considered battery-operated power tools. It shows in this light but heavy-duty model.



HITACHI WR18DBDL \$329

★★★★★

Volts: 18

Amp-hours: 3

$\frac{3}{4}$ -inch nut: 3.38 seconds

Likes: This tool has four speed settings and two impact settings, making it a good choice for disassembling parts at the bench or removing lug nuts out on the shop floor.



ROCKWELL RK2855K2 \$260

★★★★★

Volts: 20

Amp-hours: 2

$\frac{3}{4}$ -inch nut: 3.45 seconds

Likes: Weighing 3.2 pounds, it's less than half the size and weight of our heavy hitters. This makes it a great tool for assembly and disassembly in tight places.

Don't Get Burned

Dangerous and potentially deadly counterfeit products, from extension cords to cell phones, are purchased every day.

Take this extension cord, for instance. If you bought it "on the cheap," you could be... well, playing with fire. Fake products are made without safety standards, and they put you and your family at risk. Stick with reputable products from trusted sources and you won't get burned.

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SKILLS

With the right equipment, like this vintage workshop cabinet, organization can be beautiful.



ASK ROY

Popular Mechanics' senior home editor solves your most pressing problems.

BY ROY BERENDSOHN

Q My tools are in constant disarray. I often can't find what I need, and when I take my tools somewhere, I usually misplace something. Can you help?

JIM R., OKLAHOMA CITY

A I've been there. I have tools for carpentry, finish carpentry, furniture-making, plumbing, electrical, masonry (concrete, brick, and stone), basic tile work, drywall, painting, general metalwork, welding, and demolition. That's a lot of tools to keep track of.

To make sure I know where everything is, I separate my tools by task and write the contents of a toolbox on the end of it in Sharpie marker. The box may be marked as generally as "plumbing," or it may be marked more specifically as "drills and taps."

When I bring tools for a specific task, I bring the correct box and treat

it like a mother ship. I moor it near where I'm working and ferry tools to and from it using a tool tray or two. For example, if I change a faucet, I take all the tools that I need to replace the faucet out of my plumbing box and put those in the tray. Then I don't have to root around in the main box to find what I need, so everything stays more neatly arranged, including my sanity.

Q I have two acrylic sinks in a bath vanity. The one I use more often is slightly yellowed. The other one looks brand-new. How can I remove the discoloration so they match?

ED H., FORT MILL, SOUTH CAROLINA

A Acrylics can be tough to clean. Your water's mineral content, the type of soap used, and residue

from cleaners can combine to leave a hard-to-remove film.

I've had good results with Original Krud Kutter, a liquid cleaner-degreaser that works remarkably well on soap scum, if that's the problem.

Otherwise, use what the manufacturer recommends. Generally this will be a nonabrasive gel cleaner, such as Gel-Gloss Kitchen & Bath Cleaner & Polish. Apply it to a dry surface, allow the gel to dry, and then gently buff off the hazy finish. It's a lot like polishing your car, actually.

Q We got a good deal on a house sold as is, but it has wall-and-ceiling discoloration and some damaged door and window trim caused by a water leak from an ice dam. How do we fix this?

JAY G., BOSTON

A Before you start concealing the cosmetic damage, you first have to make sure the leak won't start again. Ice dams are caused by heat escaping through a house's attic and melting snow on the roof. This causes a trickle of water to run down the roof, insulated by the snow above it, until it freezes when it reaches the coldest part of the roof, the eaves. There the ice builds up and a pond of water forms behind it, eventually leaking down into the attic. To prevent this from happening again, you need to install soffit and ridge ventilation, as well as more insulation in the attic. The vents will allow cold air to enter at the eaves and exit at the ridge, keeping the roof deck cold. And the insulation will prevent heat from escaping the rooms below. Together these measures will prevent the melt that caused the leak last time.

The discolored wall and ceiling are easy to fix. Prime the affected areas with a stain-blocking primer-sealer. Cover that with a wall-and-ceiling paint. As for the trim, if it has a clear finish, it's not likely that you'll be able to easily restore its color. You can paint it or replace it. If the trim has swelled and worked loose, nail it firmly, sink the heads, and fill them. Sand the filler smooth. Prime the trim with a shellac-based or alkyd primer and apply a top coat. If you fixed the dam correctly, that should take care of it.



TELL ROY

A reader tip inspired by a recent Ask Roy topic.

THE SECOND HARDEST THING TO AIM IN THE BATHROOM

Peter Scott, a custom woodworker in Gardner, Massachusetts, has this to say about producing a flawless bead while caulking a backsplash: "Put down masking tape on both sides of the joint, leaving 1/16 inch each of backsplash and counter exposed. Once you've laid the caulk, smooth any inconsistencies with your finger. Peel away the tape after the bead has set up."



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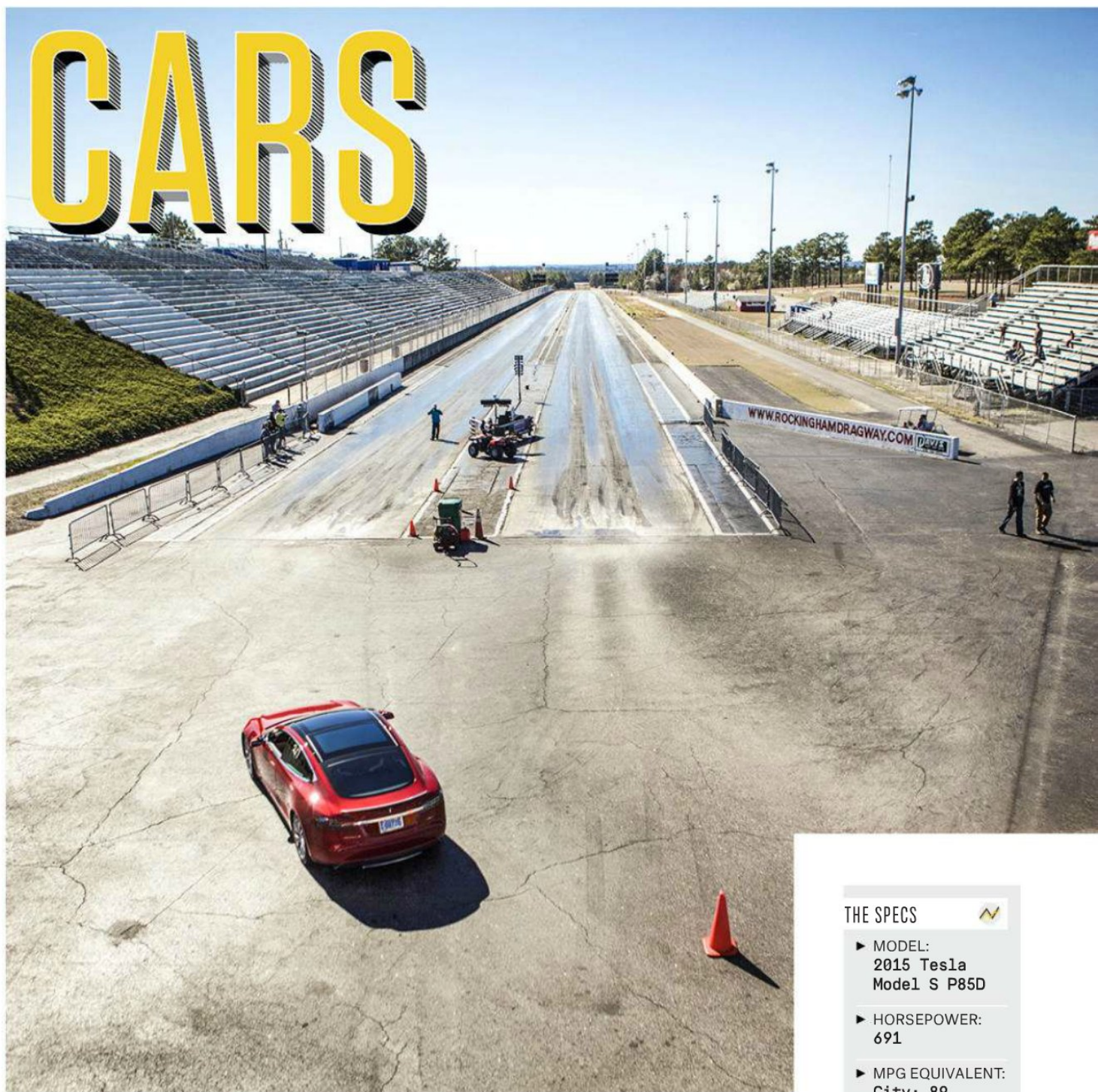


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CARS



THE SPECS

- **MODEL:**
2015 Tesla
Model S P85D
- **HORSEPOWER:**
691
- **MPG EQUIVALENT:**
City: 89
Highway: 98
- **PRICE:**
\$105,670

TESLA GOES TO THE TRACK

And pretty much owns it.

The all-electric Tesla Model S P85D became a YouTube star soon after it went on sale last December, showing up at drag strips and spanking muscle cars and exotics alike. I watched those videos and thought, I want to do that. I want to surprise a few guys who think they're about to dust a glorified Prius. So at the earliest possible opportunity, I procured a P85D and headed for North Carolina's Rockingham Dragway to hunt some Mustangs and Vettes. Activate insane mode! (Yes, to unleash the Tesla's full 691 horsepower, you push a button labeled Insane Mode.)



THE D IS THE LATEST EVIDENCE OF HOW TESLA SINGLE-HANDEDLY CHANGED THE ELECTRIC-CAR CONVERSATION.

The D, as it's colloquially known, is the ultimate Tesla, which means that it's also the ultimate electric production car. Compared with the former Model S performance champ, the rear-wheel-drive P85, the D gains a larger motor at the rear—470 horsepower—along with a new 221-horsepower motor at the front. You lose some luggage space in the front trunk, but the benefits are obvious as soon as you floor the accelerator. Electric motors make instant torque, and all-wheel drive provides ultimate traction. Combining the two results in off-the-line thrust that borders on disorienting.

I pick up the Tesla at the company's new store in Charlotte, about eighty miles from the drag strip. With an EPA-rated range of 253 miles, I could probably make it from Charlotte to Rockingham and then home to Southern Pines on a single charge. But I want to check out a Tesla Supercharger station, so I take a detour to a Texas Steakhouse restaurant 110 miles away, off I-95 in Lumberton. In the corner of the parking lot there's a row of high-speed chargers, free for any Tesla with the eighty-five-kilowatt-hour battery. While I'm inside eating a steak salad, the Model S gains 135 miles of range. The Supercharger gives me an extra stash of electrons for the track, but I suppose it would also work pretty well if you're planning a road trip. When I unplug the car

to leave, there's a second P85D parked alongside, wearing South Carolina plates. Interstate electric-car travel: It's happening.

At the strip I expect to hustle a few suckers who still associate the word Tesla with eighties hair metal—lighters up for "Love Song." But a few months after its debut, the D is already such a legend that everybody knows exactly what it is. Respect is accorded. In the staging lanes I pull up next to a Trans Am WS6 and ask, "You wanna go?" The driver scopes the Tesla end to end and warily replies, "I guess so." His reluctance is validated by the result. By the eighth-mile mark, the Trans Am is a distant spec in my rearview mirror.

Back in the pits I overhear a guy on his phone saying, "We got a Tesla here! This thing is insane, cuz!" You'd think there might be some resentment toward an optioned-out \$133,000 rich-guy ride showing up at the local Sunday fun runs, but the red Tesla seems to generate nothing but good-natured enthusiasm. I offer the shotgun seat to anyone who asks, including a track worker who introduces himself as Little Terry. "Presumably there's a Big Terry here too?" I ask. "Nope," he replies.

Little Terry and I proceed to dispatch a 2015 Mustang 5.0 in the opposite lane. Which is impressive, since it's plumbed with nitrous,

FIVE WAYS THE MODEL S DRIVES SO YOU DON'T HAVE TO



GEOCACHING SUSPENSION

The air suspension can remember where you raise it, so that when you arrive at your steep driveway or office-park speed bumps, the car will raise itself.



INTELLIGENT CRUISE CONTROL

If you're on the highway in the right lane and the adaptive cruise control slows you for a car ahead, activating the left turn signal cues the car to return to your set speed. So instead of pulling into the passing lane and waiting for the car to figure out that the road is clear, it starts accelerating as soon as you initiate the lane change.



AUTONOMOUS BRAKES

The regenerative braking is so strong that you can usually drive around without touching the brake pedal. If you actually want to use the brakes and clean the rust off the rotors, Tesla provides a mode to dial back the regen.



BUILT-IN VALET

On a conference call to announce new range-calculation software, Tesla CEO Elon Musk mentioned a somewhat more momentous Model S upgrade that's supposedly coming later this year: the summon function. "As long as you're on private property, you can press 'summon' on your phone and your car will come and find you," Musk said. "And your car will put itself to bed in the garage and close the door behind it."



OVERPROTECTIVE DOORS

If you try to move the car with a door open, it goes about five feet and then slams on the brakes. Keep that in mind if you crack the door open to eyeball your parking space—try to inch the car forward and you'll get brake-checked.

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CARS

giving it a one-hundred-horsepower boost. Its driver, a guy named Dan, got a bad launch and that was it. The P85D, you see, never gets a bad launch. Its sixty-foot times are consistently around 1.7 seconds, which means that by sixty feet, the D is doing nearly fifty miles per hour. That's bonkers.

The D loses exactly once, when Dan nails his launch and rides the laughing gas to a win. I call it a day soon thereafter, since I've noticed that each quarter-mile run is knocking five miles off my estimated range. Still, I arrive home with a hundred-mile cushion, having covered 219 miles and dusted a succession of muscle cars at the strip. The D is the latest evidence of how Tesla single-handedly changed the electric-car conversation. You don't want a P85D solely because of its carbon footprint or your position on Saudi Arabian politics. You want one because it's about the coolest damn thing on the road, a twin-motor sedan—an American one at that—that you can drive all day. The man at the track was right: It's insane, cuz.



The Model S can lower its suspension at highway speeds for better aerodynamics.

Right: Tesla's plug doesn't fit anybody else's charger, but they provide a variety of adapters.



2015 BMW i8



The BMW i8 Really Wants to Be Electric

This car shouldn't have a gas engine at all.

I finally got a chance to drive the BMW i8, and it lives up to the hype. Everywhere you go, people do double takes at the outrageous concept car with the BMW badge and the dihedral doors. The i8 is quick, it's sure-footed, and it's even a perversely good deal—\$136,000 isn't cheap, but it's downright attainable compared with the hybrid hypercars from Ferrari, Porsche, and McLaren. But there's one aspect of the car that's at odds with the overall Mission Impos-

sible spy vibe: the gas engine. As a plug-in hybrid, the i8 uses a 129-horsepower electric motor paired with a 228-horsepower three-cylinder gas engine. Building a three-cylinder car that does zero to sixty in 4.2 seconds is an achievement, but three cylinders is tantalizingly close to no cylinders. Everything about the i8—the styling, the carbon-fiber tub, the touchscreen key fob—feels like it was beamed in from the year 2050, leaving the internal com-

THE SPECS

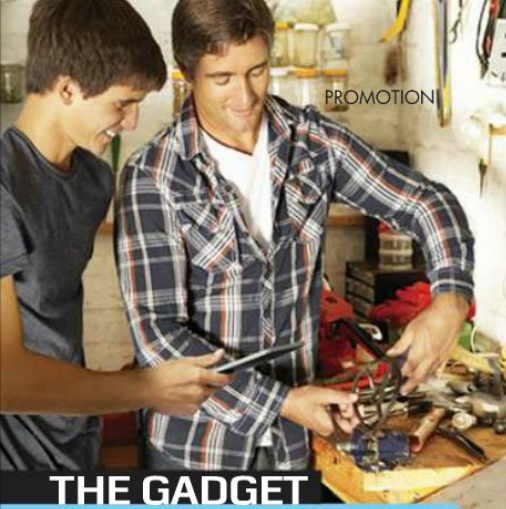
- ▶ HORSEPOWER: 357
- ▶ MPG: City: 28 Highway: 29
- ▶ PRICE: \$136,650

bustion unit as an incongruous glance backward. Some people have wondered if BMW might offer the i8 without the battery and electric motor. I'm wondering just the opposite.



BEHOLD, THE TOUCHSCREEN KEY FOB.

For a car as innovative as the i8, not any old key fob will do. That's why BMW will have an optional touchscreen one available this fall. In addition to performing typical key-fob duties, the swipable screen displays information including the car's fuel level, remaining range, and diagnostics. The fob charges in a center-console docking station and can last three months on one charge.



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REVIEWS

What we're driving now.

1

2015 VOLVO POLESTAR S60

Price: \$60,225

→ Polestar is Volvo's official tuner, a third-party speed merchant with the factory's blessing, similar to the role that AMG originally played for Mercedes-Benz. And like an AMG Benz, a Polestar Volvo is a hotter version of the everyday machines. The Polestar S60 gets a new turbocharger and intercooler, bigger brakes, a new exhaust, and a more aggressive rear-biased calibration for the Haldex all-wheel-drive system. The springs are 80 percent stiffer than the next-sportiest S60's, and the manually adjustable shocks are from Öhlins. Polestars are exclusive too. For 2015 the U.S. gets forty Polestar S60s and eighty editions of the V60 wagon. With 345 horsepower and 369 pound-feet of torque, the little S60 claws its way off the line with a sound and ferocity that bring to mind a junior Porsche 911 Turbo. While many modern cars are so assiduously refined that the rough edges are added after the fact ("We'll do the exhaust note in post!"), the S60 is genuinely, refreshingly uncouth. It's probably a little too loud, the ride a little too stiff, for most people. That's what's great about it. Polestar isn't building a transportation module that will make thousands of people vaguely satisfied. It's building a singular Swedish performance sedan that forty people will absolutely love.

2

2016 HONDA HR-V

Price: Not available

→ Small crossovers are popular because they cloak pragmatic functionality in a veneer of adventure. The new HR-V shares a platform with the Honda Fit, but offers a little more ground clearance and optional all-wheel drive. Like the Fit, the HR-V seems to provide more room inside the car than the exterior dimensions would imply, as though there's a subtle bending of time-space as you climb inside. The unusual center-mounted fuel tank means that the second-row seat can fold completely flat. In the usual Honda idiom, there's plenty of clever engineering hidden where you can't see it. For instance, under the hood. The 1.8-liter four-cylinder makes 141 horsepower and 127 pound-feet of torque. At about 5,000 revolutions per minute, a valve in the intake manifold switches over to a short runner for higher power. In other words, you want to zing this engine, which means you ought to consider the six-speed manual transmission, so you can peg the revs and fully mine what power there is. If you go for all-wheel drive, you get an automatic continuously variable transmission, but at least Honda gives you steering wheel paddles that let the CVT approximate seven fixed gears when you're feeling frisky. Assuming the HR-V crowd is ever desirous of frisky driving.

3

2015 LAND ROVER DISCOVERY SPORT

Price: \$37,995

→ The new Discovery Sport is, if we're honest, trafficking in a bit of brand snobbery. At the Sport's nakedly aggressive price point—\$37,995 to start—there are enough drivers who'd simply rather say, "Let's take the Land Rover" than "Let's take [anything else]." Catering to that desire is just good business. The Discovery Sport is offered with two or three rows, although the third row is really just for occasional use. (Rover calls it 5+2 seating, as in five adults and two kids.) I drove the Sport in Colorado, and at 9,000 feet I was glad for the 2.0-liter four-cylinder's turbocharger, which helped maintain power in the thin air. The ZF nine-speed transmission's supershort first gear stands in for a low-range transfer case, which is a good solution for occasional off-roading—likely the only kind this rig will ever see, its two-foot wading depth notwithstanding. There are spots, like the grim scatter of buttons surrounding the dashboard touchscreen, where you're clearly reminded that this ain't a Range Rover Autobiography. But the Discovery looks cool, offers a modicum of Rover off-road credibility, and doesn't cost any more than the typical mainstream crossover. For Rover, this is how you still move cars without selling out.

PopularMechanics TAKES YOU...

BACK TO THE FUTURE



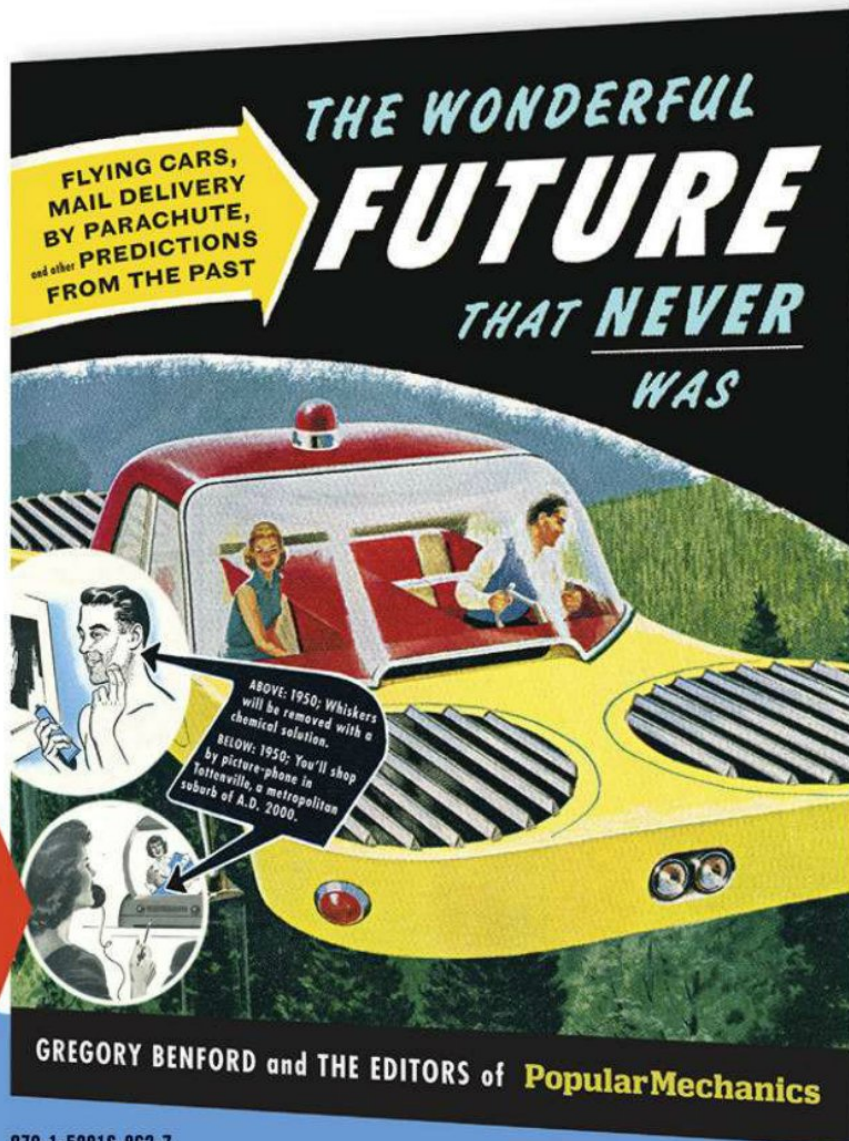
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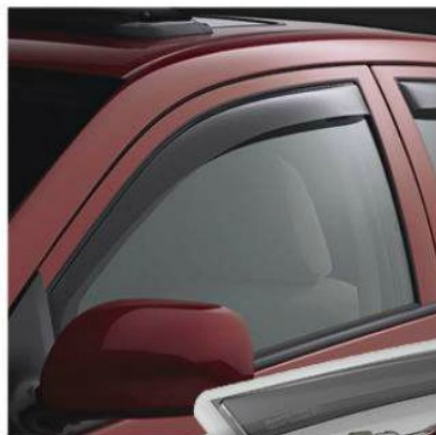
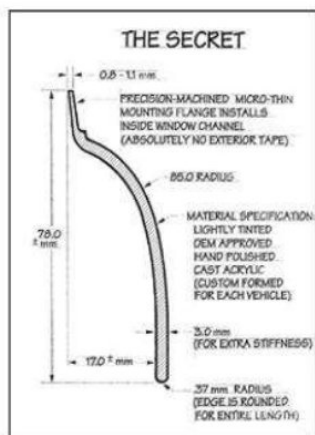
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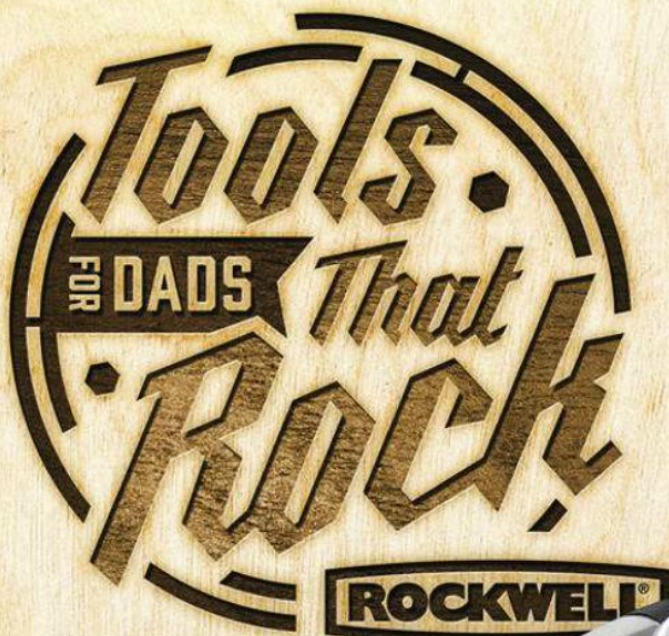
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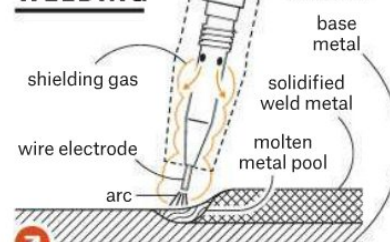


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► **THERE ISN'T ONE** welding process suitable for all applications, so you need to consider these factors: the type and thickness of the metal you're welding, how big the job is, whether you're welding indoors or outdoors, what you want the welds to look like, and your budget.

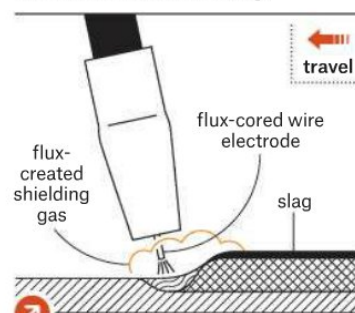
The most widely used form of welding today is electric arc welding, in which an electric arc melts an electrode (welding wire, for instance) and partially melts the base metal. When the molten metals cool, the parts fuse together. There are different types of arc welding, but we're going to concentrate on MIG (metal inert gas). A form of wire-feed welding, it's the easiest type to master, especially if you're teaching yourself.

THE PRIMER: WIRE-FEED WELDING



METAL INERT GAS (MIG)

Uses a weld gun that continuously feeds wire from a spool when the operator presses the trigger. Along with the wire, the weld gun simultaneously supplies a shielding gas that protects the metal from impurities in the air. MIG yields cleaner, better looking welds than stick welding.



FLUX-CORED ARC WELDING (FCAW)

Similar to MIG, except there's no separate shielding gas because the wire electrode has flux in its core, which creates its own shield as the wire melts. This windproof setup makes FCAW a good method for welding outdoors.

GLOSSARY

Base: The metal on which you lay down the weld.

Bead: The molten metal after it solidifies.

Electrode: Conducts

current in order to create the electric arc. Electrodes can be either consumable (MIG, FCAW, and stick welding) or nonconsumable (TIG), which describes whether or not the

electrode melts during the welding process.

Flux: In stick and flux-cored welding, flux is the material that shields the weld puddle from oxygen and airborne

contaminants. This protective layer improves the bond the filler metal makes to the base metal. A weld free of contaminants is also stronger and is often more aesthetically pleasing.

HAZ: Heat-affected zone, the area of the base metal that is not melted but nevertheless has its metallurgical properties altered by the welding process. Different metals have differing levels of thermal



2 Buy Your Equipment

You can buy a quality setup without emptying your bank account.



► WELDER

The welder is your biggest expense, so don't cheat yourself—a cheap welder will only frustrate you and make learning more difficult. A wire-feed welder uses ordinary household current to produce an extremely hot, high-energy electric arc. Inside the machine is a small motor-driven spool of welding wire (the electrode). The wire is fed down a hose to a trigger-activated welding gun. When the operator touches the wire against the base metal, the arc melts the wire and partially melts the base. In MIG welding, as long as the trigger is down, the gun keeps feeding wire and gas.

The **Lincoln Electric Power MIG 210** is new technology for a great price: At 120-v or 230-v, it allows an ambitious beginner to MIG-, TIG-, and stick-weld. It costs \$999.

At \$767 the **Millermatic 141** is a nice introductory option. It's a 120-v wire-feed welder that can be used to weld thin aluminum and steel between 24-gauge and $\frac{3}{16}$ -inch.



TIP!

Your welder also has a work lead coming out of it. This is an electrical cable with a clamp on the end that attaches to the base metal and completes the electrical circuit required to weld. If dirt, rust, or paint interferes with the lead's contact, your weld quality will suffer.



► WHY YOU WANT AN AUTO-DARKENING HELMET

The light generated by any arc-welding process is incredibly bright, and it will burn your eyes if you're not wearing a helmet. For years traditional welding helmets had a permanently darkened viewing shade, but that meant you had to flip your mask up whenever you weren't welding.

The **Antra AH6-660-0000 Solar Power Auto Darkening Welding Helmet** provides lots of options, from \$45 to \$109, depending on lens size.

New auto-darkening helmets protect against harmful light emissions by automatically darkening their clear lens to a preselected shade in milliseconds, using LCD technology in their glass. Each helmet also has controls to personalize settings.

► WELDING WIRE

Wire is relatively inexpensive. A simple rule of thumb is to use a thin welding wire on thin sheet material, and increase the wire diameter as the material's thickness increases. A welder takes at least two different diameters of wire. The owner's manual for the machine tells you what it takes, and there usually are instructions on the flip-up panel on the side of the machine. It's all surprisingly intuitive.

► GAS

Buying the right shielding gas is important, so make sure you know what type of job you plan on tackling. You can pick up a reusable tank of gas from your local welding supplier. The psi will vary depending on the type of torch you're using and how deep you want your welds, but generally you'll stick to between 15 and 25. As for the gas mixture, a home hobbyist with a wire-feed welder can usually get by with 100 percent CO_2 shielding gas. For a cleaner weld, use 75 percent CO_2 and 25 percent argon.

► OTHER TOOLS

Welding cart: Wire-feed welders can weigh up to 75 pounds, so build or invest in a welding cart to increase portability.

Awl or carbide scribe: to mark cut lines.

Right-angle grinder: for grinding, beveling, and flattening welds, as well as for surface preparation.

Miter clamp or magnet square: to secure joints.

Chipping hammer and wire brush: for cleaning up slag and spatter.

Welding pliers: to trim welding wire and remove spatter from the welding-gun nozzle.

→ GLOSSARY

► **diffusivity,** depending on how well the metal conducts electricity.

Pool, or puddle: The molten metal, before it solidifies.

Shielding gas: Inert or semi-inert gases that protect the weld area from oxidation and impurities in the air. Argon, helium, and CO_2 are the three most

common shielding gases used in MIG welding. When selecting your gas, the base material, weld properties, and cleanup all must be taken into account.

Slag: When the flux melts it emits a gas that solidifies into a protective coating called slag, which is removed during grinding.

Prepping Your Weld

③

Laying down the bead is only a small part of the process.

► Ready the metals

Use a wire brush and acetone to remove oils and dirt. If you need to cut the metal, mark a line with your awl or carbide scribe, and cut along it with a metal-cutting chop saw, a hacksaw, or

a grinder with a cutoff wheel.

► Grind the edges

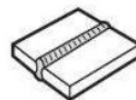
But only the ones you plan to join, and use a right-angle grinder. This is called chamfering. A chamfer is a bevel

between the adjoining edges of two pieces of material, typically at 45 degrees. This creates a space for the filler and provides greater structural integrity to your weld. Doing this for butt joints, especially, is a good idea.

► Position the metals

With your miter clamp or magnet square, secure the joints to keep the pieces of metal in the same plane before you begin the weld.

[KNOW YOUR JOINTS]



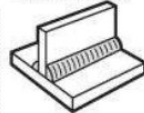
BUTT



LAP



EDGE



T

TIP!

You are dealing with sparks, fire, and molten metal, so don't start welding before putting on a welding jacket or apron, leather gloves, and a helmet. If you want to save money, a good-quality long-sleeve cotton work shirt can stand in for a welding jacket. Don't forget your work boots (no sneakers), and remove jewelry from your wrists and neck. When grinding, put on safety glasses and a full-face shield. Keep an ABC fire extinguisher nearby too.

④

Laying Your Weld

Finally it's time to melt some metal.

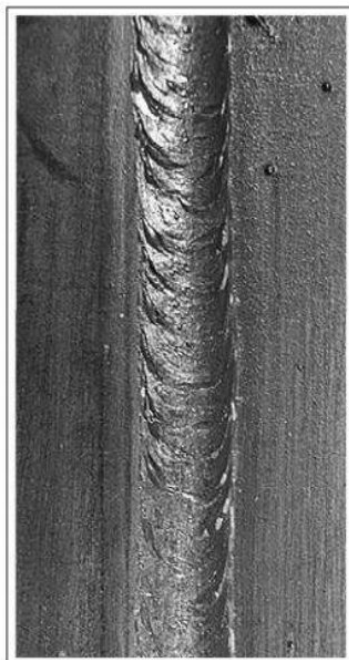
► Body and hand position

Think of the welding motion like a golf swing—you want as few moving parts as possible, and you want the motion to be fluid and repeatable. When possible, hold the welding gun with two hands, or use the wrist of your off hand to guide the hand holding the welder (think of a billiards shot). With the welder off, do a dry run to make sure your positioning is good. The steadier your hands, the better the weld.



► Tack welding

Before starting, check your gun. The wire electrode should stick out between $\frac{1}{4}$ and $\frac{3}{8}$ inch. Make sure the nozzle is clear of spatter and that the wire tip is clean. Then make a few tack welds, just enough to connect the base metals, along the joint.



“A good line of welds should look like a stack of splayed quarters.”

— STEPHEN SOMPLE,
EMPIRE METAL
FINISHING,
QUEENS, N.Y.

► The final bead

After you've tacked the metals into place, you can lay down your final weld beads. Keeping the weld gun at about a 75-degree angle to the base, move slowly from left to right (if you're right-handed), spending one to two seconds laying down each bead and maintaining a constant arc length. Don't concentrate on the bright arc. Look at the edge of the weld puddle, and when you reach the end of your weld, pull the electrode back from the metal and allow it to cool.



Grinding Your Weld

If you don't care how your weld looks, or if it's on a piece of metal that won't be visible when your project is completed, you can skip this step, because you are done. Congratulations—you've made your first welds. Work on perfecting your technique on scrap metal. Welding is a lot like playing the guitar: It's not hard to do it a little bit, but to become proficient you need practice, practice, practice.

► Flush-grinding welds

For a smooth finish, use a 36-grit grinding wheel attached to your right-angle grinder to grind along the weld path, not across it, for uniformity. Go slowly. If you grind through your weld, you'll have to start over. When grinding, you should see only orange sparks. Blue means you're pushing too hard. Once you've finished, grab a zirconia flap disc for precision shaping and finishing.

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2

OF

4

THE STALL

*Sometimes, that which stirs our greatest fears becomes the source
of our most profound joy. A story of flying.*

BY JOSHUA FERRIS

PHOTOGRAPHS BY DANIEL SHEA

WE HAVE SQUARED UP TO THE DOUBLE UNBROKEN YELLOW LINES

that separate the taxiway from runway 28 at Caldwell Airport in Fairfield, New Jersey. It is my second flight lesson inside Six-Two Romeo. My instructor is Tom Fischer: shaved head, tinted specs, a fresh company polo every day. Between lessons, Tom puts out fires set by regulators, mechanics, staff instructors, student pilots, calls of nature, and the demands of lunch. And that's just what I know about. Circling his head, who knows: forecasts, fuel costs, dreams of franchises. On the ground he can seem beleaguered. He can seem harried and curt. But put him inside a plane and the man transforms into an angel of patience and calm.

We have run through the pretakeoff checklist, which includes making sure the flight controls are free of any last-minute obstructions and that the engine doesn't peter out suddenly when throttling down. It's prudent, when taking off, to have working controls and a running engine. Before radioing to the tower to request clearance, Tom informs me that today I will be doing everything on my own to get us up into the air.

My first lesson was easy. I was so unsure of everything, so frightened and awed, that going up wasn't half as bad as all that dreadful anticipation. I'd even say it was fun. But then, Tom did almost everything: takeoff, landing, a lot of the pilotage. I turned the yoke to the left, I turned it to the right. *Wheee!* I learned where the throttle was located. "Is this the throttle?" I kept asking Tom, pointing. "Which way does it go again?"

When Tom tells me that I alone am in charge of getting us up into the air, I have to ask myself: Which one is the throttle again? Which way does it turn?

A word about your pilot: When it comes to the physical world, I've always considered myself at something of a loss. I'm talking about switches and levers, valves, winches, latches and locks, hasps, handles, knobs, and hinges. If it needs to be pushed, I pull it. If it turns clockwise, I try to yank it out. I poke instead of flip and jimmy when I should toggle.

The instrument panel on Six-Two Romeo, less involved than those you spy on your way back to coach, nevertheless bristles with knobs and switches. Now, it's one thing for me to confuse the volume knob for the input knob on a stereo receiver; it's another thing to get confused inside Six-Two Romeo, where every mis-

take is potentially fatal. Not really, or not likely, because Tom is in the plane with me. But my irrational fear isn't contained by the knowledge that Tom is in the plane. Irrational fear whistles like the wind at the windows. It kicks the stomach into gear like so much turbulence. It drowns out every word of Tom's helpful instruction.

Tom reviews how the throttle works. Then he reminds me to engage the right rudder pedal as we go down the runway. The right rudder offsets the airplane's natural tendency to yaw to the left, a consequence of the propeller's asymmetrical thrust. But overcome as I am by the anxiety of getting us up into the air alone, as we take off I forget which one I should be using. The left? The right? I decide that it must be the left. I punch the throttle in and off we go—not trending but *hurtling* to the left like a clown car under a big top.

Tom wrestles the plane under control. As it happens, we are forced to abort takeoff anyway when a groundhog pops out of its hole and scurries across the runway.

BECAME OBSESSED DURING my time in the plane with the question of initiative. How did I reach out and willfully take control of an airplane I didn't yet know how to fly? I didn't want to make a mistake.

Up there, mistakes seemed like a matter of life and death. Let Tom reach for the controls, I thought. He's the expert. But then how would I ever learn?

I'd been flying for about a month when, after a lesson of one deplorable landing after another, Tom prescribed two hours in the simulator. I was making too many involuntary mistakes very near the ground: coming in too fast, rolling the plane at the last minute, yanking up on the yoke and causing the runway to disappear beneath us. "You can't land on a runway you can't see," Tom sensibly suggested. He wanted me out of the plane and in a controlled environment where we could pause the action at the moment I made a mistake and zero in on its causes.

The dubious advantage to simulated flight is emptying the cockpit of everyone but yourself, so that you see just how spectacularly you would crash without your flight instructor beside you. It's oddly as nerve-racking as the real thing. I consistently came in far short of the runway. One landing in particular, I found myself wildly, dramatically short—so short I was on course to crash long before the runway began.

"Tom," I said. "I seem to be short of the runway."

I acknowledged the problem all right, but I did nothing to correct it. I did not raise the nose. I did not increase the power. I might have throttled all the way up and reentered the air, but that possibility didn't even occur to me. I just keep sinking until I hit the earth, which I did very, very hard. I looked back at Tom, who was sitting behind me at the computer.

"What interests me," he remarked dryly, "is why you would say that and not do anything about it."

That was the mystery! I just couldn't spur my will into action. What *is* the will? I tend to think of it as a secret power, something that erupts from me but remains independent of me. I do not *will* my will—it just is. It just *does*. But it can't do what it does not know how to do. It holds back, remains absent, is in some way in negotiation with my intelligence. They have a back-and-forth. Will:



LEARNING

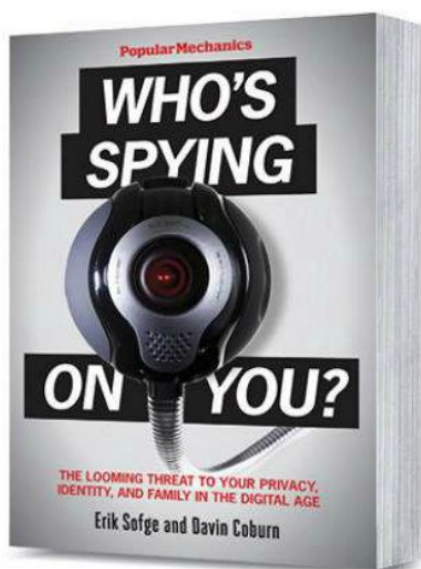
TO FLY

2 OF 4

**YOU'RE NOT
PARANOID.**

**YOU ARE
BEING
WATCHED.**

Today, our every activity can be quietly monitored, from who our friends are to all of our financial transactions. And with medical records in the "cloud" and imminent gene sequencing, even our bodies are up for grabs. What can we do? From phone hacking to identity and credit theft, *Who's Spying On You?* tells the stories of real people whose privacy has been violated, describes the technologies used to intrude, and reveals how we can protect ourselves in a world filled with spies.



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Master all the instruments and the control panel and I will fall in line. Intelligence: But how am I going to master anything when you refuse to engage? Will: I'm saving our life by not engaging, pal. Intelligence: But you're also preventing me from learning. Will: I'm preventing you from making stupid mistakes, you idiot! Intelligence: If you won't engage and I can't learn, how will we ever do a solo flight? Will: A solo flight? As in, a flight without Tom? Intelligence: That's the goal here! Will: Good luck getting me into the plane on that day.

Worried as I was that a mistake might be fatal, positive action in Six-Two Romeo would have implied that I was, in some way, okay with dying, that I had accepted the possibility. I wanted to fly, sure, but I didn't want to die.

TOM FISCHER SAYS THAT THE closest anyone comes to dying during a flight lesson is on the drive to the airport. In my case, it's true: I zoom through the city and over the bridge on roads with lunar pot-holes and dips made for motocross.

I sandwich myself between two semis on I-80 as I drift upwards of ninety miles per hour. The steering wheel is a thing of familiarity and common sense, and I can brake on a dime without thinking.

If my sense of safety and control in a rental car is an illusion, it's a useful one, allowing forward motion.

The conditions are reversed inside Six-Two Romeo. I'm surrounded by peril, I feel, and though the yoke is in hand and the throttle within reach, the illusion is one of paralysis. Lacking perfect know-how, I lack agency. I *can't* take the initiative.

Part of my inaction is due to irrational fear, and part of it is due to the many technical things I have yet to learn. I have to learn how to use the controls: the yoke, the ailerons, the rudder pedals, the throttle, the trim tab, the flaps. I have to learn how to pilot: how to climb, how to descend, how to hold a steady course. I have to learn how to use the instrument panel and how the readings work in tandem with the controls. I quickly learn that, in a medium as marvelous as air, there is no such thing as an independent change. A simple bank to the left might require a change in pitch. It might require a change in rudder. It might initiate a change in airspeed. It will almost certainly change my heading. Once I commit to memory all of these interrelated changes and learn how to anticipate, accommodate, and modify them according to my piloting goal, I have to fold in the complications of wind and weather. Once I get a handle on weather, I have to learn how to navigate over unfamiliar terrain. Once I learn how to navigate, I have to learn how to communicate with air traffic control. More daunting than any of this, I have to learn how to land.

My second lesson was more or less an introduction to all this. For my third lesson, I'm no more prepared for what Tom suggests than I was for getting us up into the air on my own.

"What maneuvers have you been reading about that you'd like to try out?" he asks on our walk out to the apron where Six-Two Romeo is parked.

I wouldn't mind the maneuver with the hot towels. Or the maneuver with the warm mixed nuts. Or the maneuver where I roll over and sleep until we're an hour outside of Shanghai.

"How about stalls?" he asks. "Should we do some stalls?"

Now, I have read about stalls, online and in books. I'm aware that they exist. The word "stall" captures the attention like little else. It evokes breakdown, arrested midair motion, an immediate and irrecoverable fall from the sky. Stall the plane by some terrible piece of luck, according to my magical thinking, and you do not live.

"You can stall the airplane?"

"Of course you can."

"And then what?"

"Then you recover," he says.

"You can recover from a stall?"

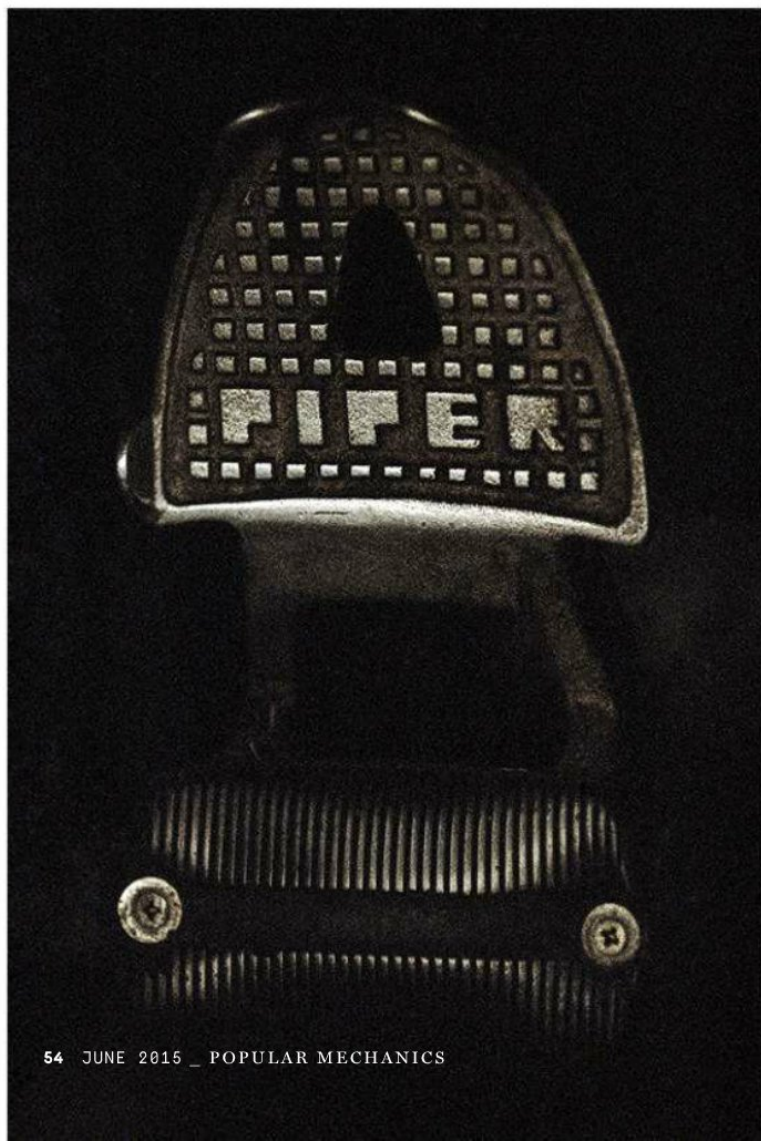
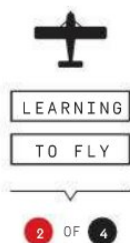
"I certainly hope so."

"And you stall the plane while inside it?"

Tom appraises me with silence and something on the borderline between confusion and derision.

"Where else would you be?" he asks.

I suspect that Tom has a hard time understanding the fear I take up into the air with me. He comes from a family of pilots and has been flying from a young age. He commands Six-Two Romeo the way John Wayne once rode a horse. And he goes up many times a day with student pilots of wildly varying proficiency, overriding all their mistakes. He has lost touch with what's scary about flying, if indeed he ever knew that fear to begin with. If he can tap into my fear, it's a





purely intellectual exercise. Which is as it should be: If he shared it, we would be two quivering ninnies hurtling to our deaths in no time at all. His confidence that we have nothing to be scared of is the only reason I ever stepped foot in Six-Two Romeo. He takes my fear as a matter of faith and I take his confidence as a matter of faith, and between us, we have almost nothing in common.

We also have little in the way of a shared language. Three-dimensional flight is conceptually challenging; grasping those concepts, envisioning them, gaining a feel for them through words alone, is next to impossible. "Guard the yoke . . . stretch out the power . . . pitch for airspeed, not the runway . . . turn longer, not steeper . . . okay, now hold it off, hold it off, you can't force a plane to land . . ." I don't understand a thing.

We do clearing turns over the onion fields. Then Tom says to me, "Okay, let's take some power out."

This is all so new to me, and I have been so chronically afraid of flying for so long that I'm possessed by magical thinking inside Six-Two Romeo. If I shift in my seat, I believe I will throw the plane off balance. If I press down too hard on the rudder pedals, my feet will plunge through the floor panel. If I let go of the yoke, the plane will nose down like a dart and explode in the onion fields.

I can't overcome my amateur conviction that every control input or change in attitude has no margin of error and is quickly irreversible, unmanageable, and doomed.

What Tom doesn't know is that I have *deliberately refrained from shifting in my seat* to magically prevent bad things—like the power going out—from happening. I have coaxed from the airplane, by the assiduous application of my ass, its promise that it will not lose power. Why would we willfully undo all of my hard work?

"Go ahead," he says.

I reach for the throttle and pull it back. The engine's roar falls to a purr, and we are suddenly floating in comparative silence. Seconds pass. I have nearly lifted my entire body off the seat in order to keep us aloft. If there were ever a moment when the plane should fall from the sky, this would be it.

But we don't fall.

We shed speed: eighty knots, seventy, sixty. We keep the nose pointed up in order to maintain our altitude, which kills our speed even further. I expect a plummet, a midair breakup.

We get only slower flight.

"Okay, now put the power back in."

I return the throttle to full power and the engine resumes its roar. I have been laboring under the illusion that something so dramatic as a reduction in power to the engine is irreversible—but I take the power out and I put the power back in, and the engine just goes along with the show.

"Now we pitch up, as we do when lifting off the runway."

I do nothing.

"Go ahead," he says. "Pull back on the yoke."

"Pull back on it? Are you sure?"

"I'm sure," he says.

"How far?"

"Fifteen degrees."

Fifteen degrees makes for a dramatic climb. We seem to be pointed at the sky like a rocket. We are taking off again from runway 28 at Caldwell—only this time at 2,500 feet in the air. This is the purpose of the power-on stall maneuver: By mimicking what might go wrong on takeoff, we familiarize ourselves with those conditions so that, should they arise at that critical time, we stand a chance of correcting them. But during practice we do so with the luxury of altitude. The windscreen fills with the white of God, and my eyesight, which guides me through most things in life, becomes secondary. A climb like this is almost entirely about the body. We seem to be inside some kind of compression chamber or intergalactic pod where there is simultaneously sensory deprivation and the introduction of an overwhelming stimulus, a vibration evolving toward a shudder, as in a washing machine with an unbalanced load. It is the opposite of that gentle float we were in just seconds ago, when things were benign and fluffy. It is everything, in other words, that I've been taught to expect from movies and nightmares of an airplane about to crash.

But we don't crash.

"Okay, now pop it," says Tom.

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Affordable *New* Digital Hearing Aid *Outperforms* Expensive Competitors Delivers *Crystal - Clear* Natural Sound

Reported by J. Page

Chicago: Board-certified physician Dr. S. Cherukuri has done it once again with his newest invention of a medical grade ALL DIGITAL affordable hearing aid.

This new digital hearing aid is packed with all the features of \$3,000 competitors at a mere fraction of the cost. Now, most people with hearing loss are able to enjoy crystal clear natural sound — in a crowd, on the phone, in the wind — without suffering through “whistling” and annoying background noise.

After years of extensive research, Dr. Cherukuri has now created a **state-of-the-art** digital hearing aid that's packed with the features of those expensive \$3,000 competitors — at a **fraction of the price**.

New Digital Hearing Aid Outperforms Expensive Competitors

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for “all things digital” caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased at a fraction of that price), yet the cost of a digital medical hearing aid remains out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense of these new digital hearing aids. Generally they are not covered by Medicare and most private health insurance.

The doctor evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version — called the MDHearingAid® *AIR* for its virtually invisible, lightweight appearance.

- ✓ Nearly *invisible*
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He wants me to pull back on the yoke all the way, to kill what remains of our lift. I do and we stall. Until now, I would have believed recovery impossible from such dramatic behavior—arresting an airplane in midair!—and that we would plummet to our deaths. And we do plummet, a little, as I push the yoke forward at Tom's instruction. We glimpse the green earth of New Jersey in the windscreen. By descending we regain speed. I pull back on the yoke, arrest our fall, and level off. We enter a positive climb and reclaim our lost altitude.

I experience all of this with the most wide-eyed wonder. More wondrous still is my active participation. I'm struck dumb by my contribution to this seemingly reckless, perfectly natural in-air performance. The plane has acted in keeping with the laws of physics and the laws of mechanics and the laws of flight schools everywhere. An airplane is not, it seems, a magical thing with occult intent. It is a dumb and analog machine that does what the wind and I ask of it.

FEAR CONTINUED TO GET ME throughout my flight training. I made big mistakes because of it. I had a bad habit of choking the stick, as if the tighter I held it, the safer I would be. But it was the opposite that holds true. The stick, or yoke, is a subtle and sensitive instrument; by throttling it in a death grip, I foreclosed all delicate input changes, continually threw off my airspeed, prompted many unwanted rolls, and turned into a loose cannon whenever we tried to land—everything I hoped to avoid by choking the stick! “Stop pinching the yoke,” Tom told me I don’t know how many times. “How would you like to be pinched?” Sometimes I think that the story of how I learned to fly resolves entirely into the story of how I learned to take hold of the yoke less like a chicken’s neck and more like a sweetheart’s hand. I couldn’t do that until I rid myself of fear.

Between my ninth and tenth flying lessons, the fever broke. I don’t know how or why. Part of it was simply accumulating time in the air. After ten or so hours, I no longer had any reason to think the plane crashed by magic. And part of it was a better technical grasp of the many aspects of flying. I gained confidence in my power to make the airplane *predictable*. That is the pilot’s preeminent goal.

But another part of it was a growing fatigue, even a disgust: I was sick of being scared. I was tired of not taking the initiative.

I wanted to fly. I wanted to have fun.

Before my first lesson, I asked Tom if I was going to die. Tom is a circumspect man, careful to choose his words, but never at the expense of a forthright answer.

“Eventually, yes,” he said. “Nobody gets out alive.”

Later, he added, “Now, are you going to live? That’s another story. That’s a subjective question. Not dying is not the same as living.”

One day, Tom and I went up with barely a word exchanged between us. We climbed out of Caldwell and over the golf course, its tiny sand traps amoeba-like at that distance. I turned over I-80, still climbing, and turned again to the downwind. I arrested the climb at pattern altitude and

called back the power from the red line. At midfield I radioed the tower for permission to do a touch-and-go on runway 28. I reduced power and began a positive descent before I turned base to final. The runway came into view and I reminded myself to go easy on the yoke. We passed over the little fence that divides the highway from the airport. I kept a steady sight picture of the numbers on the runway so as not to come up short as I had on the simulator. I came in not too fast, not too slow, not too high, not too low. I rode the flare, holding off on touching down, and at the moment of truth, slowly set the wheels on the ground. Once the nosegear kissed the runway I immediately powered up again, climbing out once more over the golf course into a fine bright winter’s day.

At the outset of my flight instruction, I did not think it possible to take the plane in hand from start to finish. Where had the will to do so come from? I didn’t know. Somehow, the will can be nurtured. Somehow it can be flexed, like a muscle, and strengthened. What a mystery! A mystery on the order of the soul.

A half a dozen touch-and-goes later, we ended the lesson, and I taxied Six-Two Romeo back to the apron. “I don’t know if you know this or not,” said Tom just before we stepped out of the plane, “but I didn’t touch the controls a single time today.” I had done everything, from first takeoff to final landing, without a single input or correction from my flight instructor.

Yes, the risk of flying in an airplane is dying in an airplane. But if I kept flying under the influence of fear, I would never have learned to fly. I would have kept Tom next to me at all times, deferring to him, living through him. God knows I wanted to avoid dying at all costs, but not if it meant not living. Nothing I learned when learning to fly was quite as important as that.



LEARNING

TO FLY

2 OF 4

— THE —
TRUST
For
Robert's
LAND

*Because we need
more places where
we can dream*

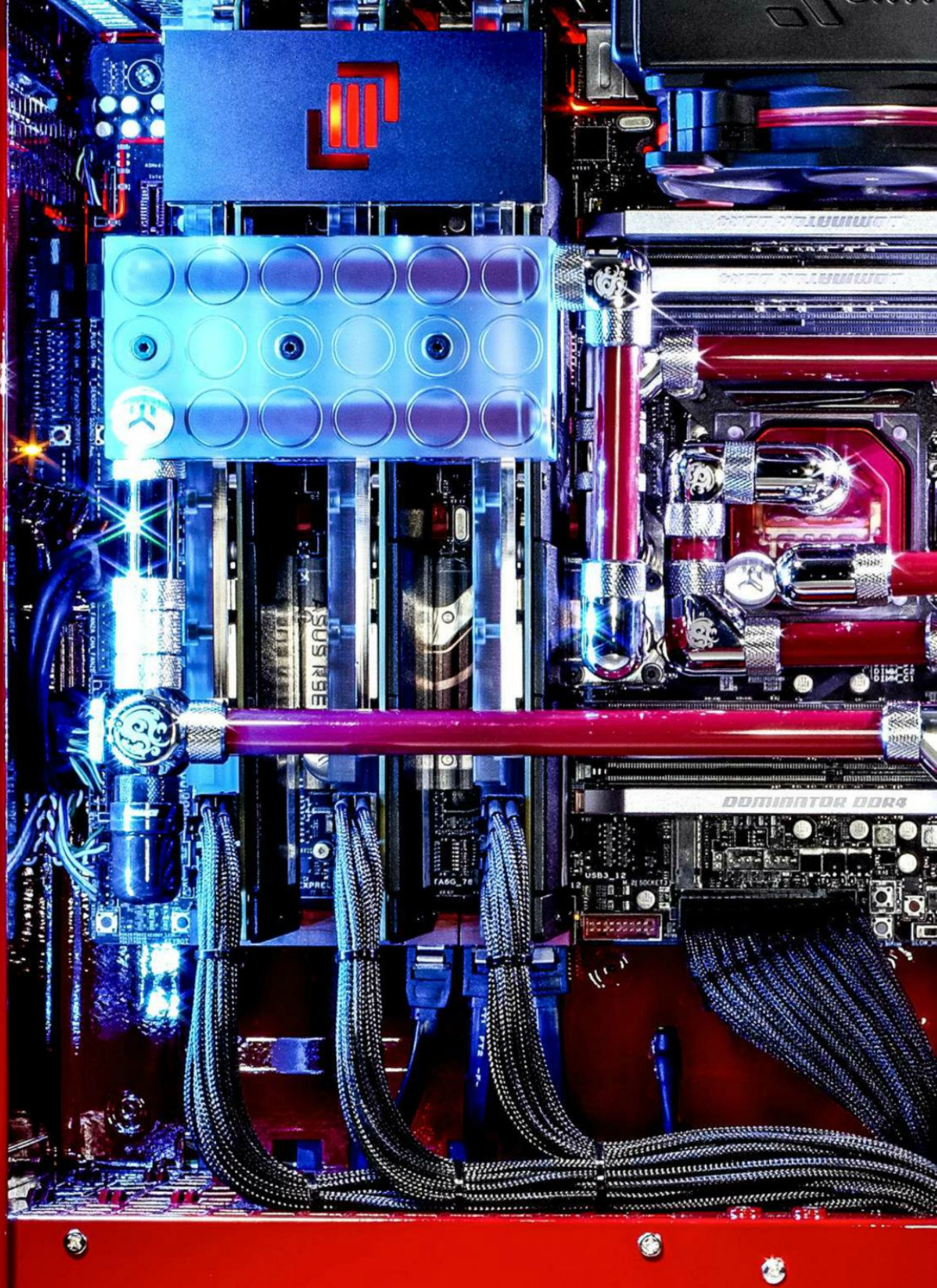


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THE
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for
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LAND





MARKET STREET in Kenilworth, New Jersey, about a thirty-minute drive west from

Manhattan, is not a sprawling coworking campus somewhere in Silicon Valley, nor is it an imposing factory in New Taipei. Yet in one of the unassuming warehouse buildings that line this drag, tucked among the auto-glass repair shop and the industrial-supply company and the diner, the techno-craftsmen of Maingear Computers do the unexpected (for New Jersey): They create monolithic desktop towers, and they do it by hand.

Wallace Santos grew up in nearby Kearny and originally wanted to be a mechanic and soup up cars. He eventually went to school to become a network-systems professional. Santos was 18 when, in 2002, he merged the two and started making modified computers. He'd put together chips and processors built for the graphics and demands of intense gamers, artfully arrange the hardware and guts inside, and take the chassis to an autobody shop to have them specially painted. Thirteen years on, Santos has twenty-five technicians who build high-performance machines for customers as varied as professional e-sport gamers, Wall Street traders, and individual enthusiasts. They've got their own paint shop in

the building now. A guy who used to do custom work on Ferraris details the exteriors.

At the facility one man is assigned to see the build of a computer through to completion. It takes about three days. New technicians sit beside a long-timer for a month apprenticing, learning how to build the machine before they're allowed to make a computer of their own. The cooling system is something of a hallmark. When you're running three graphics processing units that put out 4K-resolution graphics with incredible speed, you generate enough heat to keep a small room warm. Heat is the biggest impediment to optimal performance, so liquid cooling lets you pump nonconductive liquid around the computer's key components. The liquid carries away the heat, which is pushed out of the computer by silent fans at the top and bottom of the chassis. Rather than setting up the liquid cooling in the usual sloppy vinyl tubes, Santos and Sean Cad  t, who heads product development, created a loop of acrylic hard tubing around the PC components, the fittings made of custom chrome, and trimmed it all with a strip of remote-controlled LED lighting. It's the flourish of a dedicated gearhead. If you're going to make a machine that performs like a Formula One racer, it ought to look like it.

— MATT GOULET

A BEAUTIFUL THING

THE MAINGEAR SHIFT

COMPANY: Maingear
LOCATION: Kenilworth, New Jersey
OWNER: Wallace Santos



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OF THE ENGINE.
IT'S THE SIZE OF
THE INGENUITY.**



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F-150

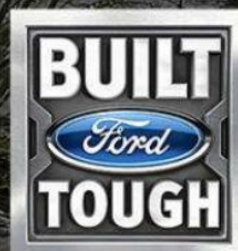
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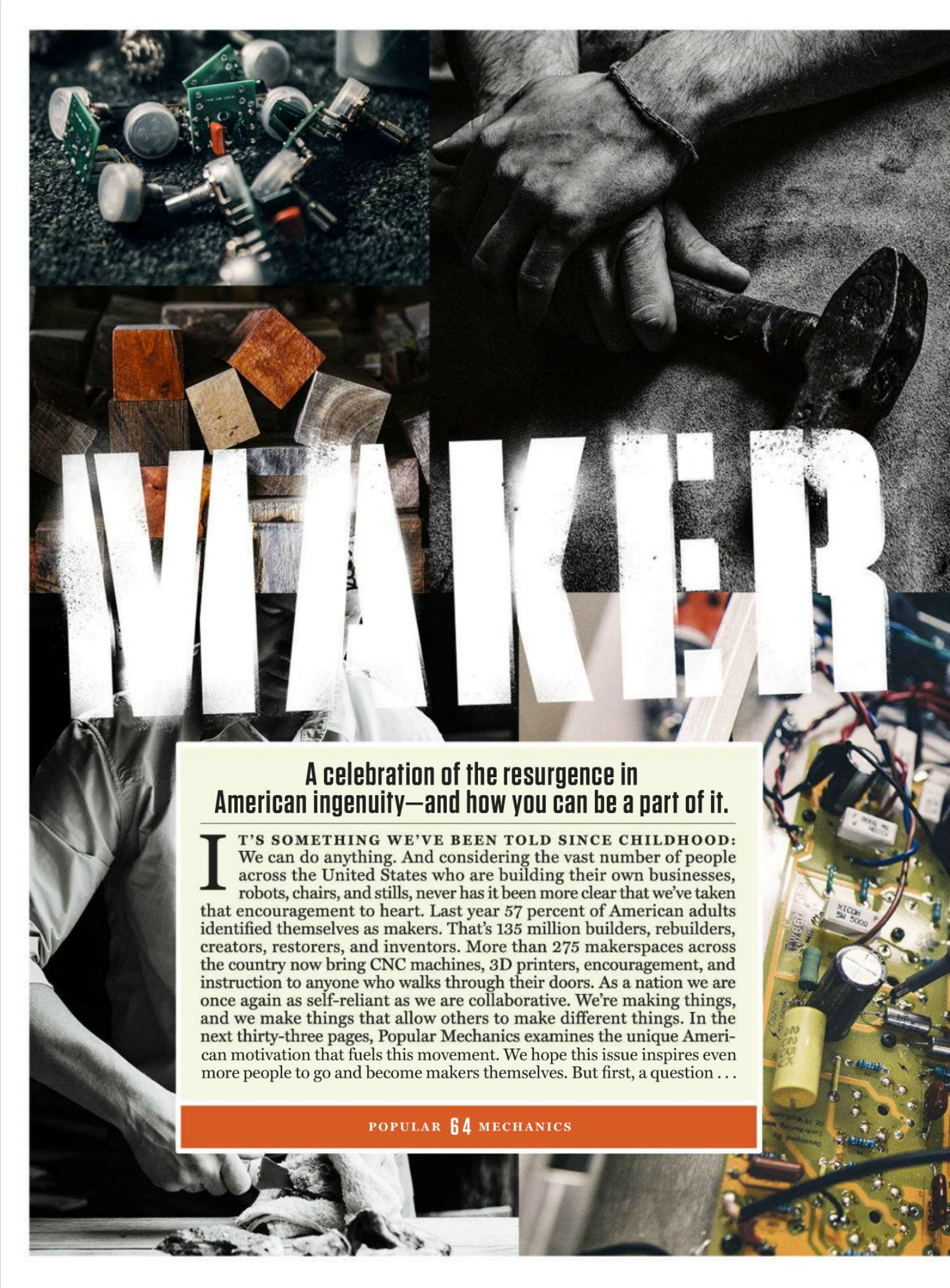
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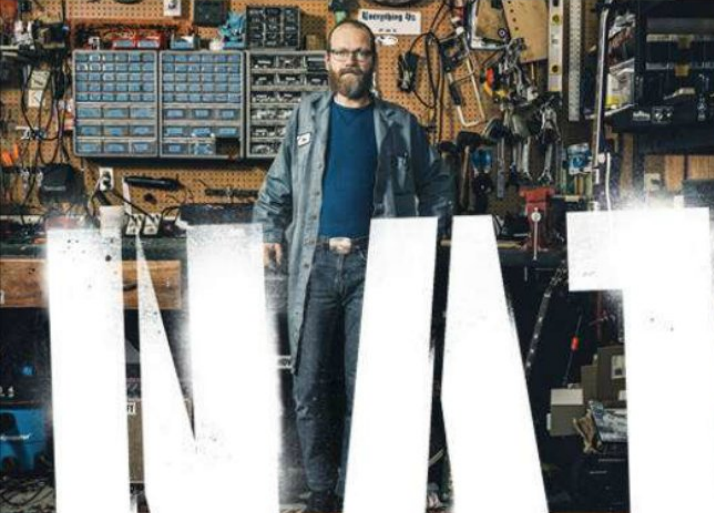




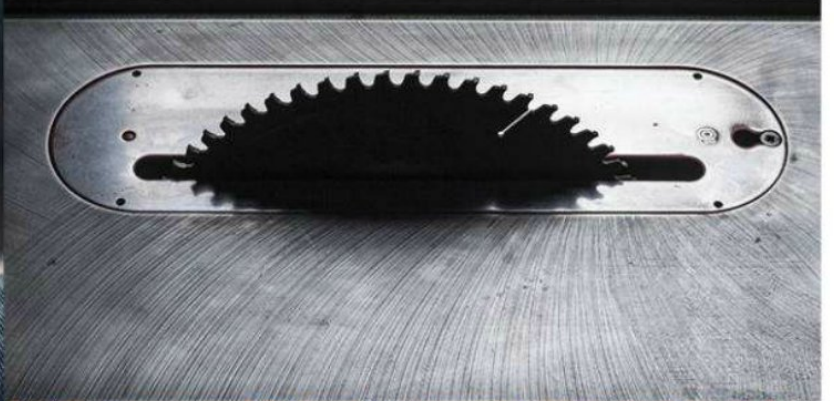
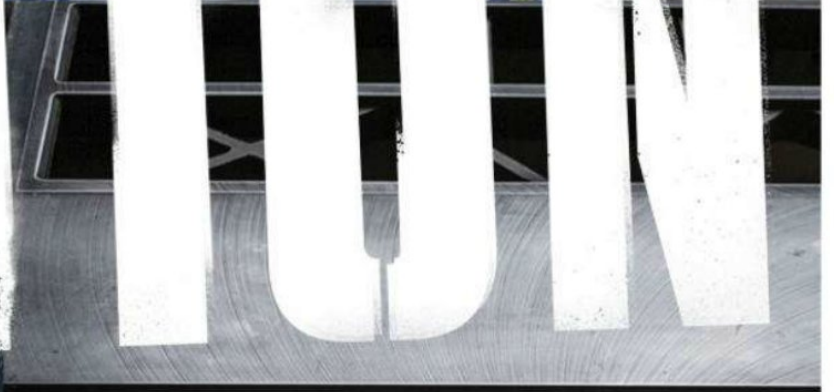
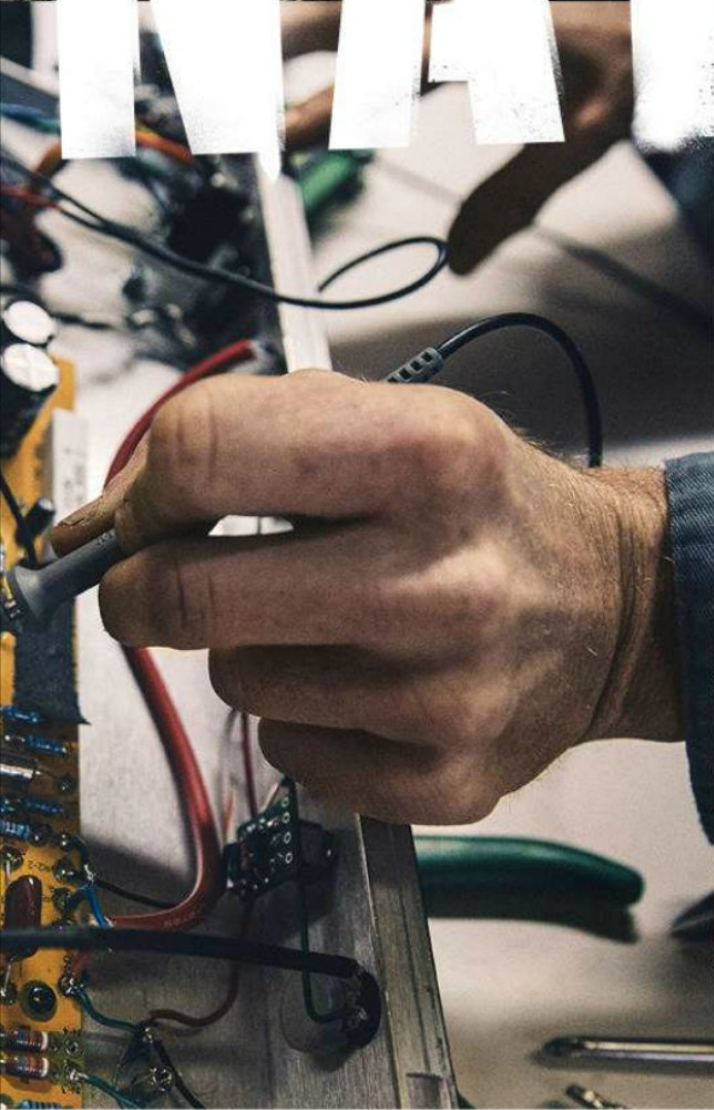
MAKER

A celebration of the resurgence in American ingenuity—and how you can be a part of it.

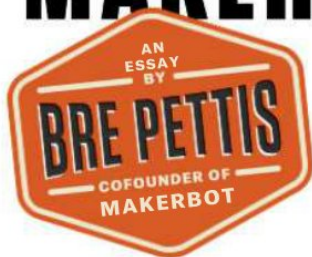
IT'S SOMETHING WE'VE BEEN TOLD SINCE CHILDHOOD: We can do anything. And considering the vast number of people across the United States who are building their own businesses, robots, chairs, and stills, never has it been more clear that we've taken that encouragement to heart. Last year 57 percent of American adults identified themselves as makers. That's 135 million builders, rebuilders, creators, restorers, and inventors. More than 275 makerspaces across the country now bring CNC machines, 3D printers, encouragement, and instruction to anyone who walks through their doors. As a nation we are once again as self-reliant as we are collaborative. We're making things, and we make things that allow others to make different things. In the next thirty-three pages, Popular Mechanics examines the unique American motivation that fuels this movement. We hope this issue inspires even more people to go and become makers themselves. But first, a question . . .



INNOVATION



WHAT IS A MAKER, ANYWAY?



getting their hands on new technology and tools. After World War II, when an analog version of today's maker movement took root, a well-equipped home workshop would have had a grinding wheel, a drill press, a great set of wrenches, and maybe even a table saw. Anyone who used those tools to fix the family car or build a picnic table or go-kart was a maker, and so were the hot rodders and *Whole Earth Catalog* devotees who followed in the 1970s and '80s. Being a maker back then—and even as recently as a decade ago—was primarily thought of as a hobby without prospects of making it your full-time gig. ¶ Today, the maker's arsenal is digitized and extensive, and likely to be found in a shared work space (see the Makerspace Directory, page 82). The core motivations are the same. Be creative and self-reliant. Feel the satisfaction of turning an idea into an object. It's one thing if you do it alone, in your shop, but another thing entirely if you do it while surrounded by other makers. The communal experience of sharing thoughts and know-how, and having access to sophisticated prototyping and manufacturing tools . . . Those are the ingredients of a mind-blowing moment for a maker. *Wow, I'm not crazy. There are lots of people who think the way I do, who believe that others might like the things I make and even pay for them.*

So, part of the answer to the question is that making today is two clicks away from becoming an entrepreneur. It's about taking the steps from self-reliance to self-employment. The path between the two can be rough. When I launched MakerBot, in 2009, I learned that starting a business requires major guts, perseverance, and stamina. It's a little easier now, for reasons I'll get into. But a fairly small percentage of people become makers with the sole intention of turning their passion into a paycheck. Most of us see a higher purpose in creating things, regardless of whether we also see dollar signs. My success hasn't come without some measure of psychic discomfort. It feels a bit odd to have merged my love of making with my livelihood. On the one hand, it's been my mission to empower the next generation with MakerBots. I have a hippie heart that wants everything to be free. On the other hand, I had to let go of being a purist to build MakerBot into a company with significant reach. It was the only way for me to turn my dream of mass-distributed manufacturing into a reality.

In 2013 the 3D-manufacturing giant Stratasys acquired MakerBot. A year later I moved on to my current project, Bold Machines, an innovation workshop that's a collaboration among Stratasys, MakerBot, and Solidscape, another 3D-printing firm. I'm back to my roots of making things, using 3D printers from those companies to empower entrepreneurs, makers, and artists. In a way I've come full circle. Bold Machines is located in the original Brooklyn headquarters of MakerBot. I'm on familiar turf with a mission that has evolved but rests on the same core principle.

I was the kid who liked taking things apart and putting them back together. My family ran a software company, and in the early 1980s my heroes were the hackers and programmers who hung around the house trying to create colors and music with an Apple II Plus. Then I got into puppetry, working in Jim Henson's Creature Shop, where I also learned about robotics. Next, I became a teacher, helping children learn different ways to express themselves. In 2004 I broke into the maker movement, when nobody really knew what it was. The definition of maker was still narrow and tethered to the past—to most it meant being a woodworker or a bike repairman. But I shot tutorial videos about makers and the things they make, and posted them on the Internet every week. Since then I've lived the extreme making lifestyle. With MakerBot I went for the holy grail of makers, to make things that make things.

I've dedicated my life to empowering creative people. The philosophical foundation of MakerBot is the same as Bold Machines'. It's a workshop where you can make anything—a movie with 3D-printed characters, the prototype of a medical instrument, or lighting fixtures that open like a flower. We look for authentic innovators and artists and designers, and we help them go from prototype to finished product, whether it's the basis of a startup or a work of art. We compress into months or even weeks a process that could take years for an individual to complete. This acceleration, the ability to ramp up from "just" making something to refining an idea or product so that it can reach its potential, is the primary dif-

We're about to see a generational shift toward greater participation in the maker movement.

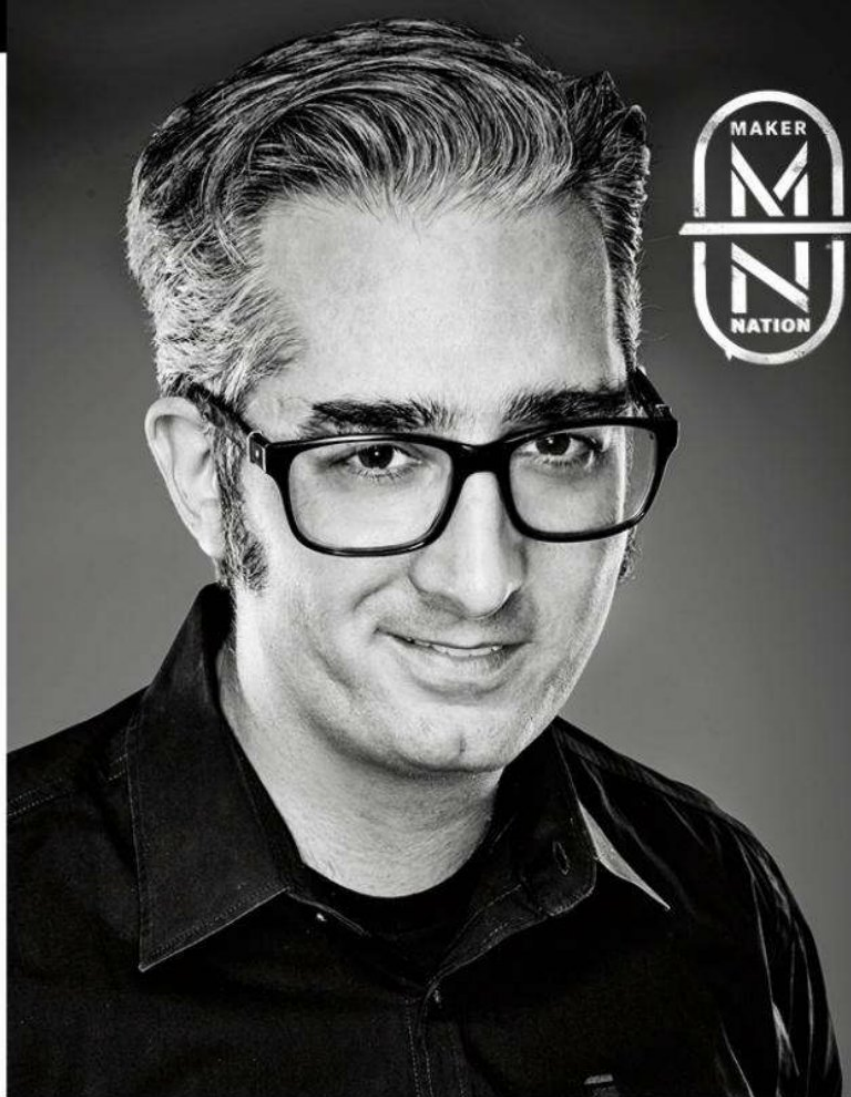
Pettis helped launch the modern maker movement with his 3D printer company. His new venture is called Bold Machines.

ference between what it meant to be a maker ten years ago, and what it means to be one now.

Another difference is the greater number of tools at your disposal. Makerspaces routinely offer the use of CNC (computer-controlled) routers, 3D-design software and printers, laser cutters, metalworking equipment, and much more. You've got Raspberry Pi, a computer in a tiny format that you can use to control physical stuff, whether you're making a computer game or building systems to secure your home or water your garden. The world of making has opened up with the democratization of tools, which was my mission in bringing 3D printers to the masses. If you are a creative person, all your excuses for not making the products of your imagination are invalid. It used to be, "Yeah, I'm creative, but I don't have the money." Well, it's affordable now. Or, "I don't know anybody. I don't have connections." Well, join a forum online, or head to a meet-up or a makerspace, and you'll be amazed at how many connections you can make.

Bottom line, the threshold to becoming a maker has shrunk, and we're about to see a generational shift toward greater participation in the maker movement. More and more people have started taking their passion and investing in it in their spare time. I would say that anybody who reads *Popular Mechanics* is someone who has the potential to be a maker. The magazine reaches millions of people. Now, they may not be makers per se. But they're open to the possibility that they could be the person they're reading about, and because making things is easier today, it's harder to ignore the lightning strikes of inspiration.

These are the makers-in-waiting. Or maybe they're like I was before I started shooting those tutorial videos—makers who have yet to identify themselves as such. In any case, I think we're on the verge of a mass realization that consumerism isn't the monoculture. As evidence I would point to things like craft brewing and distilling, crowdfunded fashion by online retailers like Gustin, and the rapid rise of the sharing economy, for which companies like Uber are the



standard-bearers. We can also look to Etsy for inspiration. Launched in 2005, the platform for makers to take baby steps into commerce now reportedly has 1.4 million sellers, 20 million buyers, \$200 million in revenue (in 2014), and is headed for an IPO.

Etsy is regarded as a primary symbol of the long-tail economy. By using 3D printing or other personal-manufacturing tools, a maker can create a one-off or limited-run item, post it to etsy.com, and then scale up production to meet demand. Some items on Etsy are tchotchkes, the physical equivalent of cat photos on the Internet. But they may also lead to innovations, like a human prosthetic device that can be developed and sold for \$300 instead of the existing industry standard of something like \$50,000. The opportunity to explore the absurd—to make tchotchkes—gives makers the freedom to come up with a new product that may seem trivial but may also contain the seed of a breakthrough invention.

I'm eager for more people to embrace this bold new approach to innovation, manufacturing, and commerce. I'd love to see schools transform from institutions optimized to train kids to take tests into places that encourage risk-taking and teach skills that are useful in the workforce. The shop classes of my youth are nearly extinct, and there aren't enough digital fabrication classes to take their place—and give students who want to make things the opportunity to explore. These are hard challenges, but they are the underpinnings of technological and social progress and also of the maker movement itself. Like any disruptive movement, some people might regard it as a fringe culture—until it becomes ubiquitous. 

**Maker 01
Fact**

05

\$93,160

Amount of money State Farm's Youth Advisory Board granted to ten girls at Philadelphia's brand-new high school, Science Leadership Academy at Beeber, to build a campus makerspace. The principal even moved the front office to give the space prime real estate.



THE NEW PIONEERS

Men and women across the country are welding, chopping, sanding, wiring, growing, building, and even sewing new ideas every day. They are part of a movement that no one started but everyone can join—an indulgence of the uniquely American desire to create.

SCULPTOR AND WOODWORKER

GRETA DE PARRY

GRETA DE PARRY'S best work has been accidental. There's no plan—no sitting down and sketching something out. She just gets to work. "To me it's the context and the process that matters so much," she says. "It's constantly doing

things, and then other things come from it." So: accidents. Like her current top seller, the Coleman Stool. After earning a degree from the School of the Art Institute of Chicago, de Parry was creating concrete seating for a private garden while, for another project, she was bending rods to make powder-coated tables. "I had all of these little concrete discs, and I stuck one on top of one of the steel bases I'd welded for the tables," she says. "It was a beautiful, simple seating object. I started playing around with that, dipping the steel into the concrete, playing with the forms, sitting on them. Some crumbled."

But eventually she had her first Coleman Stool.

It was the same with the Popular Mechanics logo she created (page 10). One of the foam letters she made fell on a screw. The screw stuck and de Parry got an idea. She filled the entire letter with screws. Then she filled the rest of them. She used silver flex duct tape to build walls around each letter, cast them in clear resin, and dipped the molds in a bucket of paint thinner to remove the foam. "It's the process of doing that gives you something really beautiful," she says. That, and happy accidents.

—PETER MARTIN



HOW TO EBONIZE WOOD

BY GRETA
DE PARRY

I no longer use store-bought stains. Just wood bleach and a homemade dark-black stain called ebonizer.

Ebonizer is an iron acetate formed by adding steel to vinegar. You can use anything, from old nail filings to steel wool. In my shop we always have a five-gallon jug of the stuff brewing. It's been going for ten years now. The color is slightly affected by how much steel you add or how long you let it brew. If it gets too dark, you can always dilute it down with a little water.

Iron acetate reacts with tannic acid, so woods such as walnut, cherry, and oak, which have high tannin levels, work very nicely. Lower tannin woods, such as birch, have a harder time taking the stain, but you can trick them by brewing black tea and brushing it on the wood, letting it dry, then adding the ebonizer. Sealing it in calls for experimentation. Try using tung oil, shellac, or West System resin. The effects are all so different—and beautiful.



NIAL MCGAUGHEY

NIAL MCGAUGHEY STARTED making amps because he had to. As a musician, he found there were sounds in his head he couldn't coax out of his speakers, so in 2009 he launched his own business, Hovercraft Amps, in Portland, Oregon. Hovercraft builds custom amplifiers that can be adapted to any taste. They're built from an array of unique materials, including used ham-radio components, office-building floorboards, and the cannibalized guts of other amplifiers. "There's a marked difference in vintage speakers that have been played through for years versus brand-new ones," McGaughey says. "A brand-new speaker will be very sharp or potentially very harsh. In an older speaker, the cones have softened up a little bit. The glue usually gets harder. The magnets lose a little bit of their charge, which changes some of their acoustic properties." It's the same with the wood: "Green wood, or wood that is just off the mill, usually has high moisture content. The glue is still in the process of drying, and the structural rigidity and acoustic properties are less than those of a piece of wood that's been sitting around for fifty years."

As McGaughey built more speakers, he developed an understanding of all the components of an amp's sound. That understanding led to a signature process McGaughey calls fettling (a term he encountered working on antique motorcycles): adjusting the multitude of fine details to make something perform rather than just operate. — KEVIN DUPZYK

HOW TO MAKE A BESPOKE AMPLIFIER

THE REQUEST:
A customer says, "I want to sound like Eric Clapton in the early shows with Derek and the Dominos." McGaughey treats these meetings like doctor consultations, emerging with pages of copious notes and a rough idea of a schematic.

THE DETECTIVE WORK:

McGaughey tracks down the sound the customer requested and reverse-engineers the ingredients of the amplifier that was used. Then he determines what components he can get his hands on that fit the recipe.

THE COMPONENTS:

Military-surplus stores, garage sales, and eBay resellers are all potential treasure troves. One surprising producer of quality components is the Russian military. Vacuum tubes from aircraft and submarines have been great eBay finds.

THE BUILD:

McGaughey's main tools are his brain, a computer, pencil and paper, and a calculator. He also uses hand tools and a multimeter.

THE FETTLING:

All the parts of the schematic are tuned to the customer's needs. For example, the parts selected for an amp are what create distortion, but the fettling process determines if it's sloppy, bluesy distortion or the angular sound of heavy metal.

THE FIRST CHORD:

For heavily customized orders, the entire process can take up to a year. The payoff is when the customer plugs in and plays for the first time. McGaughey says he's repeatedly gotten the same email: "That's the sound that was in my head!"

Maker 02 Fact

05

In 2013, after meeting a young leukemia patient who wants to be an engineer, Gokul Krishnan, a doctoral student at Vanderbilt University's Peabody College of Education and Human Development, put together colorful LEDs, a 3D printer, an Arduino circuit board, tape, string, and Lego bricks. Since then about twenty children who are isolated in their rooms for health reasons have gotten to play with the carts, as part of Krishnan's Project M@ch, short for Makerspace at Children's Hospital.





WATCHMAKER

CAMERON WEISS

For a little while, part of Cameron Weiss's watchmaking process took place in his living room. Another part in his kitchen. The first year after launching Weiss Watch Company, not all of his equipment fit in his home studio, so he had to use whatever space he could.

After dropping out of the University of Southern California in 2008, Weiss (pictured on page 65) enrolled in watchmaking school in Florida, then headed to Switzerland. He worked for iconic watch brands Audemars Piguet and Vacheron Constantin before coming back to his Los Angeles home to start his own company. His goal was to bring watchmaking back to the U.S., a country that actually has a respectable history of watch innovation (including an escapement created by Charles Fasoldt in the nineteenth century that was so stable, he would strap his pocket watch to the connecting rod of a train, then meet the train on the other side of the state to find the watch still keeping nearly perfect time).

Weiss no longer has to annex his kitchen—he has a dedicated space now, and even a second watchmaker—but he does still dream of restoring the heritage of American watchmaking. Although Weiss currently assembles his watches from mostly locally made parts, the movements are still imported from Switzerland. His next step will be to have his own movements built in Los Angeles. “We’re currently working to produce the bridges and wheels right here in L.A.,” he says. “We’ve done a prototype, and we have a functioning movement.” If he’s successful, Weiss would be the first large-scale producer of all-American watches in half a century. — P.M.

MAKER HALL of FAME



TAILOR

MARTIN GREENFIELD

HIS FATHER WAS an engineer who wanted his son to become a doctor. But his father didn't make it out of Auschwitz. No one in his family besides Martin Greenfield did. He survived in part because an older man in the laundry room of the concentration camp had given him a brief sewing lesson, instilling the 15-year-old from Czechoslovakia with the beginnings of a skill that would make him, today at age 86, America's most renowned tailor.

At Auschwitz, Greenfield was tasked with washing soldiers' uniforms. In his scrubbing he once ripped the collar of a shirt. Although he was severely beaten for it, Greenfield pilfered the shirt, now useless to the Nazi soldier, repaired it with his nascent sewing skills, and put it on under his own ragged prison uniform. From then on his treatment in the camp changed. Prisoners and guards alike saw the shirt peeking through and thought he was somebody.

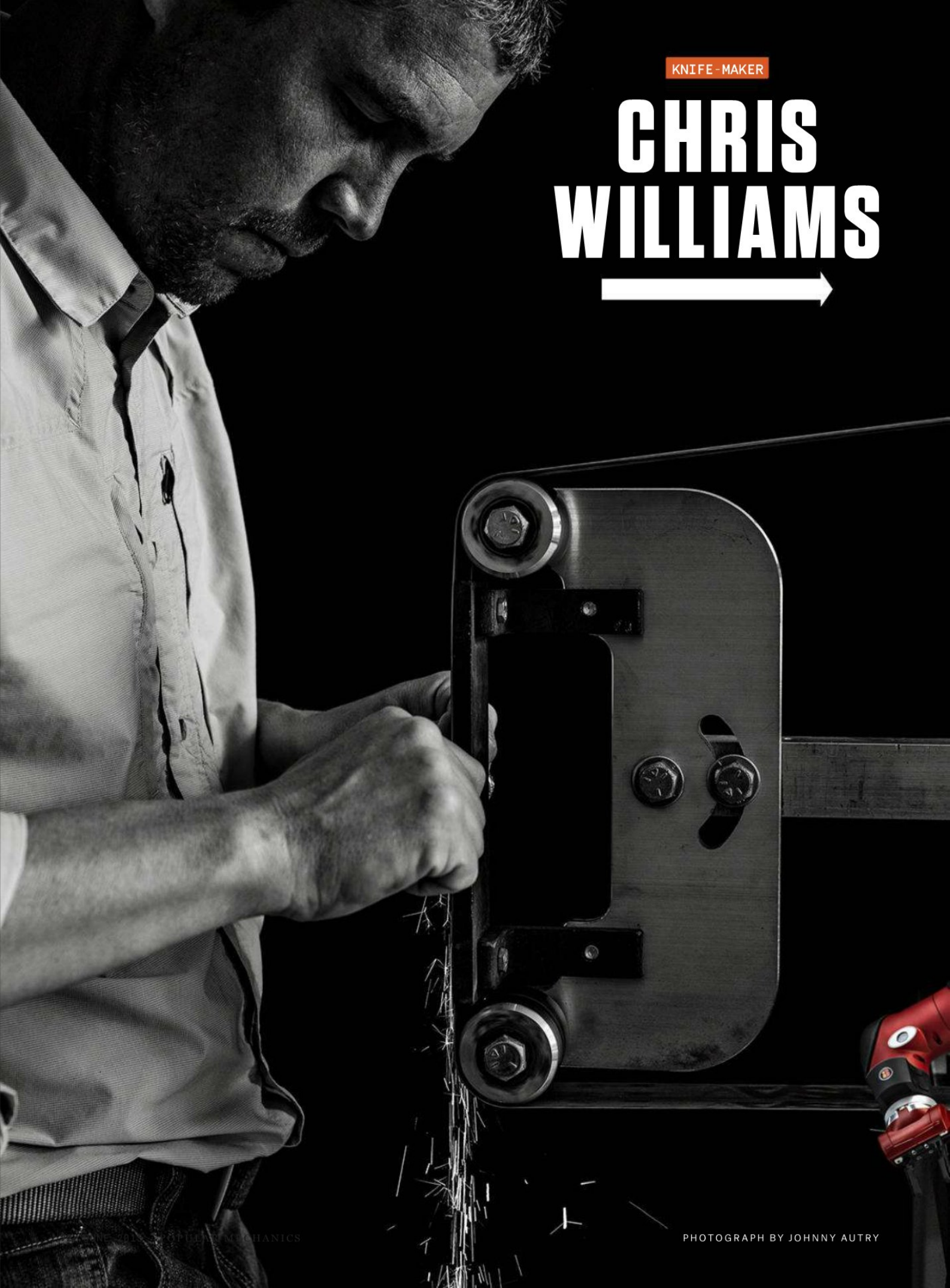
When Greenfield made it to America in 1947, he landed a job in Brooklyn at GGG Clothes, a company that supplied costuming for movies filmed in New York City

and even outfitted President Eisenhower in the fifties. He had the most menial job in the factory, moving bolts of fabric from one table to another. But as he persevered, his boss became a father figure to him and promised to make his young assistant a “suit doctor,” Greenfield says. Barely a decade later, at the age of 28, Greenfield was in charge of the entire operation. In 1977 he bought the company outright and renamed it Martin Greenfield Clothiers. “Every teacher who taught me something, I eventually became better at it than the teacher. That's the key,” Greenfield says. In the years since, he has made custom clothing for presidents Bill Clinton and Barack Obama, and many of the traditional costumes on HBO's *Boardwalk Empire*. His suits are now sold by respected fashion labels such as Rag & Bone and Band of Outsiders, and he has a special edition

of J. Crew's best-selling Ludlow suit. It's proof of the potential for success when modern makers partner with larger brands. Those brands all come to Greenfield because no one else in the country can do what he does.

— MATT GOULET

▼
**THE HIERARCHY
OF MAKERS**
Artisan
Craftsman
Hobbyist
Tinkerer
Putterer
Futzer

A black and white photograph of a man, Chris Williams, working on a knife. He is wearing a light-colored button-down shirt and is focused on his work. He is using a large, industrial-grade metal press or grinder to shape a piece of metal. Sparks are flying from the point of contact between the metal and the machine. The background is dark, and the lighting highlights the man's face and the sparks. The text "KNIFE-MAKER" is in a small orange box at the top right. The name "CHRIS WILLIAMS" is in large white letters with a white arrow pointing right below it. The text "PHOTOGRAPH BY JOHNNY AUTRY" is at the bottom right.

KNIFE-MAKER

CHRIS WILLIAMS



THE WILLIAMS KNIFE Company's Edisto is unique among oyster knives: It's beautiful. Instead of a blade like a Phillips head and a plastic handle, the Edisto has an hourglass shape with a beveled steel blade attached by ram's horn to a wood-grain handle. "There's no reason it can't be elegant as well as functional," says founder Chris Williams. "Functional is the hard part. Pretty is the easy part." He's not kidding. The knife took Williams over a year in his shop on Johns Island, near Charleston, South Carolina, and fifty different prototypes to perfect.

Williams learned knife-making from his grandfather. The first few he made for himself, then he started making knives for friends. Strangers saw those knives and requested their own, and soon Williams was able to quit his job in the financial sector and turn his hobby into a legitimate career. Six years in, business is so good that he's opening a second shop.

Although the Edisto was designed specifically for the small shells of the oysters from South Carolina's Low Country, it'll work just as well on a couple dozen bluepoints. The blade's four sloped edges get into the tightest of shells, and the thickness of the middle retains lateral strength for spreading shells open. They're proven too. Williams says a customer bought a blade for his brother, who had consistently placed second in the amateur division of the National Oyster Shucking Contest. Since receiving an Edisto blade he's won the past three years in a row.

— CAMERON JOHNSON



FARMER

DENZEL MITCHELL

Although he started out growing food for his family and neighbors on an abandoned lot in Baltimore, Denzel Mitchell's monetizing plan was to supply regional chefs with rare heirloom produce historically found in the kitchen gardens of the area's enslaved Africans.

His first restaurant cash crop was Genovese basil, a Mediterranean relative of the native West African herb, customarily planted to ward off evil spirits. Then in 2008 Mitchell met restaurateur Spike Gjerde, known for sourcing exclusively from the Chesapeake Bay watershed. At the top of

Gjerde's wish list was the heirloom fish pepper, a nineteenth-century chili, once a staple of regional seafood cooking. Mitchell grew the pepper, and Gjerde bought the entire crop. "As part of the Bay's culinary heritage, I knew the fish pepper needed to be on plates in Baltimore," says Mitchell, a history teacher and food educator. "But this was the first time I worked with a chef who made that same cultural connection."

Named for Mitchell's five children, his company, Five Seeds Farm, has since brought forth other heirloom crops, including North Carolina black

THREE TIPS THAT'LL MAKE YOU A BETTER GARDENER

BY DENZEL MITCHELL

- 1 Mulch your plants with shredded newspaper, shredded leaves, or old hay to conserve water and nutrients and suppress weeds.
- 2 The best fertilizer is worm castings, a pure and natural source of water-soluble nutrients.
- 3 To repel critters, sprinkle cayenne pepper around the plants.

peanuts (a New World version of the subtropical Bambara groundnut, used in African folk medicine), the Southern green-striped cushaw squash, and a previously unknown variety of sweet potato, Mr. Mason's sweet. As an agricultural entrepreneur, Mitchell's purpose is twofold: to create a viable business model to inspire young farmers, especially those of color, and as an African-American family man, to make sure storied foods stay on the table.

— FRANCINE MAROUKIAN

▶ THE THREE- QUESTION QUIZ: ARE YOU A MAKER?

1. Do you make anything?

A. Yes
B. No

2. Is it something people
other than you might be
interested in?

A. Yes
B. No

3. So interested that they'd
be willing to pay for it?

A. Yes
B. No

If you answered Yes to one or more questions, congratulations: You're a maker.

ROBOTICIST

RODNEY BROOKS

IF YOU'VE EVER used a Roomba, you can thank Rodney Brooks. The former director of MIT's Artificial Intelligence Laboratory cofounded iRobot, the com-

pany responsible for the mesmerizing self-navigating vacuums hated by dogs everywhere. He also created Rethink Robotics in Boston, a manufacturer of intuitive robots that can cheaply compete with foreign labor. Rethink's first product, Baxter, is able to perform menial tasks and work safely alongside humans. This spring the company launched Sawyer, a smaller robot with a seven-axis arm that can snake its way among complex parts on an assembly line. Even a nontechnical human guide can quickly assign tasks. Just grab the arm and position it as you respond to prompts on the robot's tablet "head." Sawyer also automatically adjusts its claw/hand to the orientation of different parts. The target use for Sawyer is testing circuit boards, tending machines, and performing other tasks conventional robots are too unwieldy to perform. "Our main contribution is designing robots with sensors and software that finally do what the public has assumed robots have been doing all along now," Brooks says. Except for planning the uprising. — DAN DUBNO





CARMAKER

JONATHAN WARD

After
Before

**THE ONE
RESTORATION
TOOL
YOU NEED**
BY JONATHAN WARD



NOT MANY PEOPLE can afford Jonathan Ward's cars (they'll run you a couple hundred thousand), but that doesn't mean we can't all appreciate them. His boutique company, Icon, takes vintage vehicles—Ford Broncos, Toyota FJ40s, Chevrolet Thriftmasters—and completely overhauls them with new mechanicals, updated electronics, and a distinctive new aesthetic. It's "classic transportation revisited in a modern context," Ward says.

The idea for Icon came after Ward helped Toyota design concepts for the FJ Cruiser, an update on the company's original FJ40 Land Cruiser. It got Ward thinking about the vehicle he would make, and in 2005 he built the first Icon FJ, right after teaching himself the skills he needed to do it. "I took extension classes, night school, University of YouTube," Ward says. "It took being a crafty scrapper to figure it out."

Icon is located in a 44,000-square-foot garage in Los Angeles, where, outside in the parking lot, a fleet of battered vehicles sit, waiting to be reincarnated. There are also a few candidates to become either a Derelict or a Reformer, Icon's newest offerings. With the Derelicts, the company updates essentially everything you can't see while leaving the car's decades-old patina. The Reformers get the same treatment—plus a new paint job.

Ward wants Icon to keep growing, but the dependence on finding suitable old vehicles and the complexity of production put a limit on scale. That's why he's also looking into collaborations with established carmakers and even venturing into new segments, like furniture and watches. Whatever he decides, it's safe to say the result will be as functional as the original. And even more beautiful.

— ANDREW DEL-COLLE

► Steel wool is a restorer's best friend. I use it for bringing back original stainless and chrome finishes, for prepping surfaces, cleaning glass, anything. Just make sure to use No. 0000, as any other grade will screw up whatever you're working on. For cleaning glass, combine it with traditional Colgate toothpaste. Coca-Cola works great on chrome.

DISTILLER

CHIP TATE



Before he can make his new stills, Chip Tate has to make liquid-cooled welding gloves. Otherwise, the Texas whiskey-maker might turn his hands into crisps as he builds the six copper stills for his new distillery, Tate & Company. "I'm one of the few that still uses direct fire as opposed to steam to heat the still," Tate says. "You have to use much thicker metal." That direct flame imparts subtle flavors, thanks to the additional heat it produces—anywhere from 500 to 800 degrees Fahrenheit. And that heat requires those special gloves. The radiation alone is enough to catch standard welding gloves on fire.

Tate didn't set out to be a still-maker. Seven years ago, when he was preparing to open his first distillery, Balcones Distilling, the stills he ordered needed modifications. So he did them himself. Since then Tate has continued to make his own equipment—an impressive feat considering he taught himself how to weld while "tinkering away" in his shop. Once Tate gets his new distillery running, he plans to build and sell stills to others. "I'm finally admitting I'm a still-maker," he says. "This is just something I do, apparently." Something he does very well, as legions of whiskey lovers will attest. — A. D. C.

HOW TO
WELD
COPPER

BY CHIP TATE

It takes a lot of heat to melt the thick copper sheets I work with, and the welders that use a mix of carbon dioxide and argon just aren't powerful enough. That's why I use helium instead of argon. It doubles the voltage of the welding arc. So if I'm welding 1/2- or 5/8-inch-thick copper, I'll preheat to at least 500 to 800 degrees and then use 400 or 500 amps with helium.



For a more comprehensive lesson in welding, [turn to page 47.](#)



HEADPHONE - MAKER

JOHN GRADO

Grado says. But then he got the idea to make headphones, even if it meant he and his wife would have to assemble them by hand. Which they did. Twenty-five years later Grado no longer has to build the headphones himself, but he still works constantly to improve their design, sometimes even while he's asleep. In fact, the brand's signature mahogany ear cups were the result of a middle-of-the-night epiphany. Like speaker casing, wood flexes and breathes to produce a natural sound. But that wasn't enough for Grado, so the newest models have an angled grain structure that reduces standing sound waves, meaning less interference between the music and your ears.

The family-run company is now on to a third generation (John's son Jonathan is the head of marketing). With the headphone market booming and a vinyl resurgence driving phonograph cartridge sales once again, it'd be no surprise if they reached a fourth. Or fifth.

— ALEXANDER GEORGE

Maker 03
Fact

05

Last year Democrats Mark Takano and Tim Ryan and Republicans Mick Mulvaney and Steve Stivers founded the Congressional Maker Caucus, a group that promotes awareness of the maker movement in government. So far, they've briefed Capitol Hill staffers on the implications of 3D printing, and have featured guest speakers from MakerBot and the Girl Scouts.





AXE-MAKER

GENE LEE

WHEN HE FIRST started making axes, Trust Co. founder Gene Lee had a problem: He didn't

know how to make axes. So he asked. "My parents immigrated to America in the seventies," Lee says. "I didn't grow up with anyone in my family having this knowledge. So when I started getting interested in it, it was just asking the right people, talking to woodworkers, metalworkers, and leatherworkers." Lee walked into shops around Portland, Oregon, and the maker community happily indulged him. Which is why, now that Lee and his current business partner Lane Clark have established themselves as restorers of stunning vintage axes, their process isn't a secret. In fact, they want people to ask questions. "We get an inquiry a week about how we do what we do, and how someone else can do it themselves." As a very brief FAQ, Lee walked us through the basics. — KATIE MacDONALD

1 Lee finds used axe heads in antique stores and at estate sales, keeping an eye out for anything made before the 1970s, when American steel production began moving overseas.

2 Rust and nicks are removed—in best-case scenarios with sanding and an angle grinder for the worst. Recently the company began using electrolysis to convert the rust into iron.

3 The head is reshaped and balanced for safety, then sharpened and sealed to prevent future rust.

4 An American-made hickory handle is attached, along with a custom leather sheath.



BREWER

ANDRÉS ARAYA

Araya is the founder of **5 Rabbit Cervecería** in Bedford Park, Illinois. The Latin American-style brewery is named for one of the mystical Aztec gods of excess.

► **Heritage:** After college at Purdue, I returned to my native Costa Rica to work in a brewery and then in consulting. Although it is slowly changing, in Latin America beer is a monopoly. Variations are mostly in branding, not flavor. I did a blind taste test with a corporate-brand manager, and he couldn't even recognize his own products. That helped me realize it was time to make Latin American craft beer that truly reflects the richness of our culture.

► **Process:** As a first-time brewer with a unique idea,

I had no proof of concept to attract investors, so I jobbed out production. I quickly discovered the downside: Contract brewers typically use one standard house yeast and a base malt, and there is no way a single variety works for all our different beers. Also, as you can imagine, people aren't necessarily willing to do what we do—for example, hand-peeling cases of limes to get the essential oils from the zest, with no pith. I couldn't live with the tradeoffs, and a year and a half later we were up and running at our own brewery.

► **Ingredients:** We do not top off a standard base beer with supplemental flavors, like an IPA with added grapefruit. Our approach is more culinary, building the identity of each beer from the bottom up. We then introduce our Latin-influenced ingredients, like the roasted-on-premises ancho chilies in our 5 Vulture Oaxacan-style dark ale. How much we add, when, and for how long, develops the unique flavors. Our inspiration comes from our culture. — AS TOLD TO FRANCINE MAROUKIAN

HOW TO TWIST METAL

BY NICK WICKS MOREAU



Every time you heat a piece of metal to red-hot, you take it out and work it until it gets cold. That's called a heat. If you put the metal back in the forge, that's another heat. To make a reverse twist, like this one (above), you pull the metal out and spin it one way with a twisting fork. Then you heat it up again, and twist it in the other direction. The process gives the metal all these reversals.

If you see a fence with upright pickets that are twisted, chances are they were made by a machine. There are machines now that are so strong, they can bend metal while it's cold, and their twists are very uniform. A reverse twist, on the other hand, is like a thumbprint, proving that a person worked the metal. There's no way a machine did that.

A blacksmith, Nick Wicks Moreau, is shown in a workshop, wearing a red long-sleeved shirt, a brown leather apron, and safety glasses. He is holding a hammer and working on a piece of metal held in a large, dark metal vise. The background is filled with various tools and equipment, including a workbench, a vice, and a large metal block. The lighting is dramatic, highlighting the blacksmith's face and the tools he is using.

BLACKSMITH

NICK WICKS MOREAU

THE FIRST TIME Nick Wicks Moreau worked with metal—during a pottery firing at a friend's house when a rod in the kiln turned white-hot and became as pliable as butter—he knew he wanted to do it again. All he needed was a mentor. Soon after, he moved to Edinburgh, Scotland, where there is a long, venerated metalworking tradition, to start graduate school in environmental resource management. But Moreau was too nervous to cold-call blacksmiths. It took him a while to find Jim Whitson, a half-hour outside town in a hamlet full of sheep. Eventually Moreau walked into the shop and asked if he could help. Whitson said no. But a few weeks later he called to say he'd changed his mind, and Moreau got to work.

When his visa expired a year later, Moreau returned to the U.S. He began helping his grandparents clean up their house in Danbury, Connecticut, and discovered a workshop in the garage. Moreau's grandfather and great-grandfather, he learned, had been welding instructors. They had started a manufacturing company called Wicks' Products. "As I cleaned, I found more and more—hammers, oxyacetylene tanks, and my great-grandfather's welding table," Moreau says. Though he hadn't planned to stay in Connecticut or to continue his metalwork, he found himself in an ideal position to do both. In 2013 he reopened his grandfather's shop, which had been dormant for more than two decades, under the name Wicks' Forge. In Moreau's family, he says, there's a second history—an alternate family tree of makers, metalworkers, and artifacts. In bending and selling music stands, gates, and furniture, he found the perfect way to keep it growing.

— JACQUELINE DETWILER



Eddie Van Halen with his famously customized guitar, Frankenstrat, at his workshop in Los Angeles.



EDDIE VAN HALLEN

IS GOOD

He's also an inventor and patent holder who has spent the better part of thirty-five years in his shop, deconstructing and rebuilding guitars and amps, searching for his signature sound. Insight from a rock legend and insatiable tinkerer.

By **Eddie Van Halen**

Photographs by **Nigel Parry**

I'VE ALWAYS BEEN A TINKERER.

It comes from my dad. Growing up, we lived in a house in Pasadena that had no driveway. You used an alley that ran through the middle of the block, behind all the houses, to get to your backyard or the garage. Well, the neighbor behind us had a U-Haul trailer up on car jacks and loaded with cinder block. One night my dad came home from a gig at three in the morning. He had a little heat going, he'd had a few drinks, so he says, "This thing is blocking me from getting in again." So he got out of the car and tried to move it. As soon as he lifted the trailer, the jack fell over, and it chopped his finger off.

This was a problem. Besides the obvious reasons, he played clarinet and saxophone. On a sax, you don't need to seal the hole with your finger. A valve closes over it. But with a clarinet, you have to seal the hole, so he took a saxophone valve cover and adapted it to work on his clarinet.

Another funny thing was later in his life, when he started losing his teeth. You need your bottom teeth to play a reed instrument. Instead of going to the dentist, he made himself a perfectly shaped prosthesis out of white Teflon that filled the gap where his teeth were missing. He slipped that in when he had to play. Watching him do that kind of stuff instilled a curiosity in me. If something doesn't do what you want it to, there's always a way to fix it.

STOCK GUITARS

My playing style really grew from the fact that I couldn't afford a distortion pedal. I had to try to squeeze those sounds out of my guitar. The first real work I did was in my bedroom. I added pickups, because I didn't like the sound of the originals. I couldn't afford a router—I didn't even know what a router was—so I started hammering away with a screwdriver. That didn't work at all. Chunks of wood flew off and there was sawdust flying all over the place. But I was on a mission. I knew what I wanted and I just kept at it until I finally got there.

Most guitar necks are too round on the back, so I took sandpaper and reshaped the neck to be very flat. I actually refretted a few guitars early on because I wanted to shave the fingerboard down and make the neck

even flatter. The flatter it was, the farther I could bend a string without fretting out, or choking the sound when the string hits a fret higher on the neck. The other issue, with Fenders, at least, was the clear lacquer they'd put on the neck. When you sweat, your fingers either slide all over the place or get sticky. I couldn't stand that, so when I built my first guitar, I used natural wood. My own sweat and oil would soak in to make it smooth. It took a lot of playing to get it that way but, eventually, it just felt so much better than any synthetic product you could put on there.

THE WHAMMY BAR

Vibrato bars (also called whammy bars or tremolos) just didn't stay in tune. The problem was the nut—the string guides at the end of the guitar neck. On the first album I used a standard, nonlocking Fender tremolo. The string is angled down from the nut to the tuning pegs, creating tension that, after the string slides back and forth when you use the whammy bar, keeps the string from returning to its original slot. I made my own nut with really smooth indentations—big and round like the bottom of a boat. I put a drop of 3-In-One oil in there, too, so the string would be extra slippery. On top of that, instead of winding the string down on the tuning peg, creating an angle and causing that tension, I would wind it up so that, from the nut all the way back to the bridge, the string was level. Otherwise there could be hangups in the nut that would make the guitar go out of tune when you went crazy on the whammy



PLAY LIKE EDDIE

Or at least look a little more like him when you do play. Eddie started manufacturing his own equipment in 2007 under the brand EVH Gear. His newest offering, the Wolfgang WG Standard (far right), launched in the spring. Named for Van Halen's son, the entry-level guitar is made from extremely lightweight and porous basswood, providing the perfect resonance for musicians who are heavy on the treble and fade. The neck is maple, with a deliberately minimal satin finish. "The more porous the wood, the more tone you're going to get," Van Halen says. "My guitars aren't sealed, so they breathe. The sap can escape, allowing the wood to age." If you get good enough to really wail, the specialty Floyd Rose bridge locks the strings to the body in two places instead of just one, so the guitar stays in tune, even when you hit a dive bomb—the high-pitched whine at the end of the song that you know you're going to try.

bar. The only problem this caused was when you hit an open string, where your fingers aren't holding it down. Without that tension, the string would pop out of the nut slot, so I'd have to remember to put my finger on the far side of the nut to hold things together.

AMPS

If it was movable, or turnable, or anything that resembled something that could go up or down, I would mess with it to make the amp run hotter. I opened the amp up and saw this thing. I found out later it was a bias control, which controls the power to the output tubes. I'm poking around, and all of a sudden I touch this huge blue thing and my God, it was like being punched in the chest by Mike Tyson. My whole body flexed stiff, and it must have thrown me five feet. I'd touched a capacitor. I didn't know they held voltage.

The Marshall amp I brought home from the store where I worked was only good if you turned it all the way up. Any lower and you'd lose the distortion. I needed that, but it was impossible to play anywhere with the volume that loud, so I tried everything, from leaving the thick plastic cover on it to facing it backwards to putting it face down. I'd blow a fuse twice an hour.

Luckily, I stumbled onto the Variac transformer soon after. I'd bought another Marshall amp, and I had no idea that it was actually a European model. I plugged it in, and I'm waiting for it to warm up and thinking, I got ripped off here, there's no sound coming out! Pissed off, I came back an hour later to give it another shot. I'd left the amp on the whole time. I didn't know it was set on 220, so when I turn my guitar on it sounds like a full-blown Marshall, all the way up, except really, really quiet. That was when I realized there was something going on with the voltage. There were these cheesy light dimmers in the house, and I hooked it up to one of those. Of course I wired it backwards and shorted out the whole house, so I went down to a place in Pasadena and asked if there was some kind of industrial-size variable transformer that would let me adjust voltage, and they introduced me to the Variac. It's just a huge light dimmer. I plugged it into the amp and controlled the voltage from that. That became my volume knob. I would set the voltage depending on the size of the room we were playing, getting all that feedback at any volume.

PICKUPS

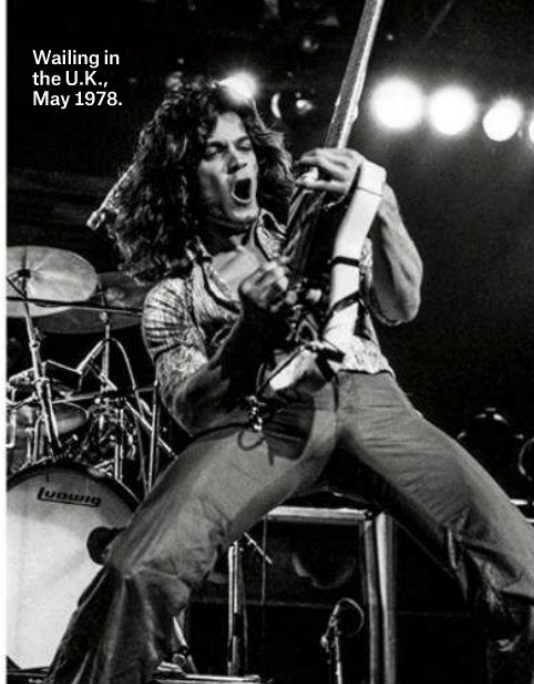
My first real guitar was a Les Paul Goldtop. I was a total Eric Clapton freak, and I saw old pictures of him playing a Les Paul. Except his had humbucking pickups, and mine had the soapbar, P-90 single coils. The first thing I did with that guitar was chisel it out in the back and put a humbucker in. When we were playing gigs, people kept saying, "How is he getting that sound out

of single-coil soapbar pickups?" Since my hand was covering the humbucker, they never realized that I'd put it in.

When my guitar was black and white, I cut out my own pickguard so it would cover the holes from the pickup I'd removed. But when I painted red on top of the black and white, which is how it is now, it didn't look cool with that black pickguard. It covered most of the paint job. I decided just to take the switch and cram it in the middle and put a nonworking pickup in the front because I didn't use it. I wasn't trying to trick anyone. Bottom line is, I didn't know how to hook it back up.

The last real step for me was adding paraffin wax to my pickup. Pickups can have this really high-end squeal, like the annoying screech of feedback you sometimes hear when someone speaks into a microphone. I thought maybe what was causing that with a guitar was the coil windings vibrating. So what I did—and I have no idea where this idea came from—was buy a hot plate and bricks of paraffin, and borrow a Yuban coffee can from my mom to put the wax in. Of course I ruined a lot of pickups, because the plastic frames would melt before I had a chance to yank the pickup out. But finally, when I had a chance to really keep an eye on it, as soon as I saw the pickup start to heat up and shrivel a little bit I'd yank it out. Man, the first time I put that in—between the Variac, the beast that Marshall was, and now the pickup not having unwanted feedback—the combination was just ideal. That was heaven to me. When all those things came together, it was like, okay, I'm going crazy with the whammy bar, I got my Marshall with the Variac, there's no stopping me.

Wailing in the U.K., May 1978.



The Patents of Eddie Van Halen

He had three. One expired earlier this year. Two remain.

U.S. PATENT

#388117

Guitar peghead:

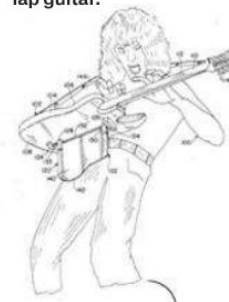
► Placing the tuning pegs on the opposite sides of the headstocks helps the strings hold tension. It also obviates the need for string trees, guides that clamp down on your strings and hinder string replacement.

U.S. PATENT

#4656917

Musical instrument support:

► A bracket that swings down from the back of the guitar, supporting it at a 90-degree angle from your body and letting you play the instrument like a lap guitar.



Actual patent illustration!



From left: the 5150III Combo amp (\$1,818), Wolfgang Special (\$1,537), Stripe Series Black and White Stripes (\$1,100), and Wolfgang WG Standard (\$733).



MAKERSPACE

(mā'kər-spās)

1. (n) a collective workshop in which anyone, including you, who wants to make or design anything can meet, work, share ideas, pick brains, and have access to the tools he needs to complete a project, including computer and design software and prototyping and fabrication mechanisms such as CNC routers, laser cutters, 3D printers, metalworking machinery, and more.
2. a fully equipped public workshop beyond your wildest dreams.
3. a place you should seek out immediately, using this list as a starting point.

A NATIONAL DIRECTORY

ALABAMA

Foomatic Makerspace
MONTGOMERY // Supports a thriving arts scene.

Makers Local 256
HUNTSVILLE // Inspired creation of another makerspace, Red Mountain Makers.

Red Mountain Makers
BIRMINGHAM // Members hacked a Power Wheels toy car so it could reach 25 miles per hour.

ALASKA

Anchorage MakerSpace
ANCHORAGE // Wood and metal shops, 3D printing, and, um, hydroponics.

ARIZONA

TechShop Chandler
CHANDLER // See "TechShop" (opposite).

HeatSync Labs
MESA // Skilled craftspeople volunteer to teach and participate in projects for free.

ARKANSAS

Arkansas Regional Innovation Hub
NORTH LITTLE ROCK // The STEAM Lab suits teenagers as well as certified engineers.

Imaginations Created
BENTON // Offers cooking classes, because makers get hungry too.

CALIFORNIA

Fab Lab San Diego
SAN DIEGO // See "Fab Lab" (opposite).

OC Makerspace
HUNTINGTON BEACH // 3D-printing heaven, with equipment by MakerBot and Fortus.

Vocademy
RIVERSIDE // After visiting here, Mark Takano, D-Calif., cofounded the Congressional Maker Caucus to support the maker movement.

COLORADO

Solid State Depot / The Boulder Hackerspace
BOULDER // See if the space is right for you at the Tuesday Meetup.

TinkerMill
LONGMONT // Teaches brewing and makes TinkerBeer.

CONNECTICUT

Fairfield County Makers' Guild
NORWALK // Free classes on Thursday nights.

NESIT Hackerspace
MERIDEN // Located in the building where the famed Springfield rifle was once made.

FLORIDA

Makers Square
FORT LAUDERDALE // Repurposed shipping containers serve as work spaces.

Tampa Hackerspace
TAMPA // Houses full-scale TARDIS time-travel machine from *Doctor Who*.

GEORGIA

Freeside
ATLANTA // The Ham Shack here caters to ham radio geeks, who still exist.

Geekspace Gwinnett
LAWRENCEVILLE // Night-owl makers love the open 24/7 policy.

HAWAII

Oahu Makerspace
HONOLULU // Weekday hours 4 p.m. to 9 p.m. only, to allow time for surfing.

IDAHO

Make It at the Library
21 LOCATIONS AROUND THE STATE // Run by Idaho Commission for Libraries.

MakerPoint Studios
SANDPOINT // Also offers custom design and fabrication services.

ILLINOIS

Pumping Station: One
CHICAGO // Attend Beer Church and pray for hefty pours of house-made brew.

INDIANA

Club Cyberia
INDIANAPOLIS // Monthly sci-fi double-feature movie night. Woo!

IOWA

Ames MakerSpace
AMES // A modest space looking to grow.

QC Co-Lab
DAVENPORT // Uses Co-Labulance, a converted ambulance, for road trips and events.

KANSAS

Lawrence Creates Makerspace
Lawrence // Makers and fine artists welcome.

KENTUCKY

LVL1 Hackerspace
LOUISVILLE // Lots of gear for aspiring electronic musicians and filmmakers.

LOUISIANA

IDIYA
NEW ORLEANS // The pride of Nola's maker community, now in a new storefront.

MAINE

Open Bench Project
PORTLAND // Classic skills, like blacksmithing, coexist with digital-age prototyping and manufacturing.

MARYLAND

Catylator Makerspace
SILVER SPRING // Summer camp for children ages 12 through 17 fills up fast.

MASSACHUSETTS

Artisan's Asylum
SOMERVILLE // Has a great screen-printing shop.

TECHNOCOPIA

WORCESTER // Working to convert former industrial spaces into housing and studios for makers and artists.

MICHIGAN

All Hands Active (AHA)
ANN ARBOR // Extremely well-equipped and among the oldest continually operating makerspaces in the nation.

GR Makers
GRAND RAPIDS // Spon-

sored by Tekton tools, GR Makers is stocked like a Nascar pitstop, but also has advanced manufacturing equipment.

i3 Detroit

FERNDAL // Aerial dancers have dangled from the rafters on colorful fabric swatches a few steps from the state-of-the-art laser cutter.

MINNESOTA

Duluth MakerSpace
DULUTH // A new space with ambitious expansion plans.

Northeast Makers
MINNEAPOLIS // Free one-on-one instruction for members makes the \$200 monthly fee easier to justify.

MISSISSIPPI

DIYneurotech
JACKSON // Regional headquarters for both Google Developer Group and littleBits.

MISSOURI

Cowtown Computer Congress of Kansas City
KANSAS CITY // The name says it all.

Hammerspace

KANSAS CITY // Offers consulting to people who aspire to open a makerspace of their own.

GCAA Makerspace
ST. LOUIS // Located in Grand Center Arts Academy, a public charter school, this makerspace is packed with students before and after school.

MONTANA

Bozeman Makerspace
BOZEMAN // Learn to make rocket cars and robots. Or don't, if you're just no fun.

Missoula Public Library MakerSpace
MISSOULA // Free for K-12 students.

NEBRASKA

Omaha Maker Group
OMAHA // Welcomes adults and kids to work on projects.

NEVADA

The Generator

RENO // A hangar-size space to build large installations for the Burning Man festival.

SYN Shop

LAS VEGAS // Supports entrepreneurship programs at UNLV.

NEW HAMPSHIRE

Port City Makerspace

PORTSMOUTH // It's a traditional makerspace, but quirky enough to offer lock-picking classes.

Makelt Labs

NASHUA // Dispatches makers to local libraries to teach skills such as soldering.

NEW JERSEY

FUBAR Labs

HIGHLAND PARK // Even hacked the acronym (for Fair Use Building and Research).

Maker Depot

TOTOWA // Offers 3D-printing service in case you don't want to learn how to do it yourself. But you should. It's the whole point of this list.

NEW MEXICO

Parachute Factory

LAS VEGAS // A nicely equipped makerspace in a town of 15,000 residents.

Quelab

ALBUQUERQUE // More of a meet-up, coworking, and hacker space, the tool inventory is growing,

and the community spirit is big.

NEW YORK

Maker Space at NYSCI

QUEENS // Ideal spot for adults and their kids to work on projects together.

SALT Makerspace

SYRACUSE // Divided into dirty (carpentry and metal shops) and clean (computer and 3D-printing labs).

Tech Valley Center of Gravity

TROY // Written rule for all members: "Be excellent to each other."

Collab

MANHATTAN // Members created the Makr Shkr robotic bartender, which makes drinks ordered via an app.

NORTH CAROLINA

The Forge

GREENSBORO // Jobs program puts members back to work by teaching skills in demand by local businesses.

Hackerspace Charlotte

CHARLOTTE // Members painted a massive QR code on a nearby roof, in case you're arriving by helicopter.

OHIO

Columbus Idea Foundry

COLUMBUS // Date night is a hit.

The Manufactory

CINCINNATI // Stockpiles used equipment and parts for new-member projects.

FAB LAB

83 LOCATIONS IN THE U.S.,
MORE THAN 500 WORLDWIDE.

A spinoff from MIT's Center for Bits and Atoms in Cambridge, Mass., Fab Lab hacker- and makerspaces are free or available for nominal fees. All fly under the Fab Lab banner, but come in many sizes (larger Fab Labs stand alone, smaller ones may be found in schools and libraries).

OKLAHOMA

Prototek OKC

OKLAHOMA CITY // A key location for the city's large meetup.com community.

GeeksOK

DAVENPORT // Okay, we get it.

OREGON

ADX

PORTLAND // Makers and artists display and sell their creations at Maker-Flat, a local home for rent to tourists.

PENNSYLVANIA

MAKESHOP

PITTSBURGH // Located in the Children's Museum of Pittsburgh.

NextFab

PHILADELPHIA // Supports the local startup scene.

Department of Making + Doing

PHILADELPHIA // A collective space for several maker groups.

RHODE ISLAND

FabNewport

NEWPORT // Offers summer maker classes for students age 11 and up.

SOUTH CAROLINA

Makelab Charleston

NORTH CHARLESTON // Members made a weather station for the space—a weather station!

SOUTH DAKOTA

Lake Area Technical Institute MakerSpace

WATERTOWN // Great Idea contest awards student entrepreneurs.

TENNESSEE

Knox Makers

OAK RIDGE // Top-notch digital-security program.

Midsouth Makers

MEMPHIS // A member made a floating beer-pong table, because he could.

TEXAS

Dallas Makerspace

CARROLLTON // Food- and bio-based classes in home brewing, gardening, rain harvesting, and more.

Houston Makerspace

HOUSTON // Center of the local maker movement, with 8,000 square feet of shop space and a 1,000-square-foot community garden.

UTAH

Make Salt Lake

SALT LAKE CITY // Videos on the shop website offer tutorials on equipment use so you can show up ready to make.

VERMONT

Burlington Generator

BURLINGTON // Maker-in-residence program offers a \$1,000 stipend to a member every two months.

VIRGINIA

Hacksburg

BLACKSBURG // Discounted for Virginia Tech and Radford University students.

Nova Labs

RESTON // Backs high schoolers in annual FIRST Robotics Competition.

Tinkersmiths

CHARLOTTESVILLE // Free workshops on metal-working, woodworking, and Arduino- and Raspberry Pi-based projects.

WASHINGTON

Gorge MakerSpace

WHITE SALMON // Just a year old, but has already held more than thirty-six classes and workshops for more than 300 8-through 18-year-olds.

Metrix Create:Space

SEATTLE // Makerspace-cum-incubator has launched businesses, including ClearShot, the world's thinnest smartphone tripod.

WISCONSIN

Appleton Makerspace

APPLETON // The Distributed Hacker/Maker Network made this its first shared makerspace in 2013.

The Bodgery

MADISON // Named for the British term "bodge," which means to repair hastily.

WYOMING

Wyoming TinkerSpace

CHEYENNE // Gamers flock to monthly tournaments.

TECHSHOP



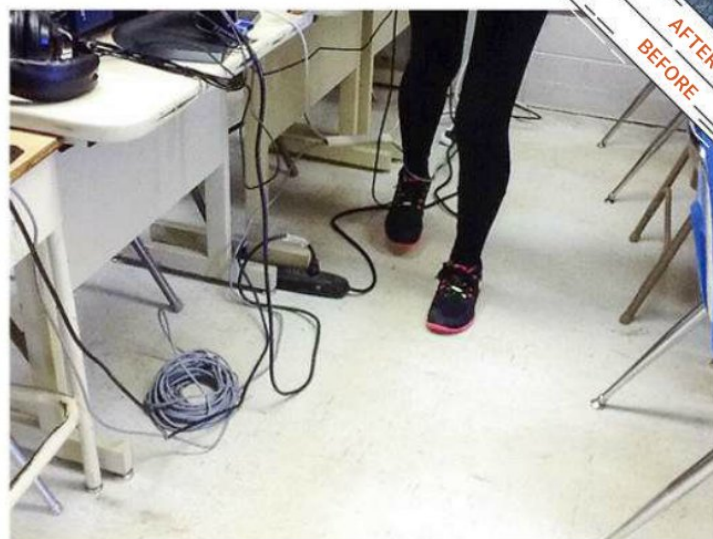
CHANDLER, ARIZ.; REDWOOD CITY; SAN FRANCISCO; SAN JOSE, CALIF.; ALLEN PARK, MICH.; ROUND ROCK, TEXAS; PITTSBURGH; AND ARLINGTON, VA.

TechShop offers thousands of members expert instruction, meet-ups, and access to more than \$1 million of advanced-manufacturing equipment. Its name is synonymous with the maker movement and its growth.

MAKING GOOD

Many American schools in poorer communities need textbooks and ball fields and higher teacher salaries. They also need something Popular Mechanics can help provide: furniture. The desks and tables and shelves that are the infrastructure of everyday learning. We partnered with DonorsChoose.org, a remarkable organization that helps teachers crowdfund projects in their own classrooms, to find teachers in need. We then connected the teachers—one at an elementary school in rural Alabama, one at a high school near Detroit—with makers whose skills matched the projects. The results were inspiring. Twenty-four craftspeople (from TechShop, the national makerspace chain, and Foomatic Makerspace in Montgomery, Alabama) volunteered to build exactly what the students needed. One man drove 850 miles to deliver custom-milled furniture parts and then spent two days assembling them. We were humbled. The teachers were grateful. The kids? They were psyched.

BY Joe Bargmann



SKIPPERVILLE, ALABAMA

LONG ELEMENTARY SCHOOL COMPUTER LAB RENOVATION

Milled at TechShop Austin–Round Rock
on ShopBot PRSalpha routers.

15	30	01	26
tables	chairs	cord-management system	sheets of ¾-inch birch plywood

Eight makers ran the routers for eighteen hours to cut wood parts.



Skipperville is a small town in the rural expanse of eastern Alabama above the Florida panhandle, where people work hard but money is hard to come by. Four years ago its local grade school—George W. Long Elementary, enrollment 482—set up a modest computer room for its students. Donated machines sat on a mishmash of secondhand desks. Cords and power strips coiled in messy tangles on the floor, and students would often trip over them, accidentally unplugging the machines. The access to personal computers was great, a coup for a small, financially challenged country school. But the room was a mess. Teacher Charisse Snell and her students called it the Wired Jungle.

That's the name she posted on the website of the

crowdfunding charity DonorsChoose.org. Snell requested new desks, chairs, and a cord-management system. The cost was \$4,717. A few months later, in March 2015, the post had yet to attract any contributions.

When Popular Mechanics discovered the project and brought it to the attention of Joe Birdwell, a cofounder of Foomatic Makerspace in Montgomery, he asked, "What can I do?"

Within a week he had recruited eight makers, including a cabinetmaker and a computer-assisted-design expert, and set up a basecamp on the Web. It served as the project's hub, connecting Birdwell's team with Snell, school administrators, Popular Mechanics editors, and TechShop in Round Rock, Texas.

The computer lab upgrade became a rallying point for makers, students, and the community. Members of the school's football team helped carry the furniture parts to the lab, and local stores donated the paint and carpet.



It's fair to ask why a makerspace 823 miles away figured into the Skipperville project. The answer is that the deadline was tight, so Birdwell decided to use open-source plans for the computer desks and chairs and mass-produce the parts. The Texas TechShop was the only place with the equipment to suit the deadline and the fabrication demands.

The eight TechShop locations are well-stocked with advanced manufacturing tools. The Austin-area shop is especially rich in woodworking machinery, including two large-scale ShopBot computer-controlled routers. TechShop volunteers manned the machines on three overnight shifts, carving parts from $\frac{3}{4}$ -inch furniture-grade plywood based on plans downloaded from opendesk.com. Birdwell flew to Austin, rented a truck, and delivered the parts to Skipperville, where Foomatic members Erin Redd and Tim Messick joined him.

There they found the computer lab freshly painted and carpeted. Within forty-eight hours they had assembled and put the furniture in place and tamed the wires with cord-management hardware. (Popular Mechanics covered materials and transportation costs.)

"All of us took computer classes as kids, but we also had shop classes," Birdwell, 34, says. "We wanted to bring a different perspective to the [Skipperville students], the actual hands-on making. Everything doesn't just come store-bought. I think it's important for them to see that."

The students adjusted quickly to the new classroom configuration, and now it's tough to get them to leave, Snell says. "When the teacher for their next class comes to get them, they're like, 'Aw, do we have to?' They love the new lab."

Teacher Charisse Snell and maker Joe Birdwell assemble the second of thirty chairs for the overhauled computer lab at Long Elementary in Skipperville.



EASTPOINTE, MICHIGAN

EAST DETROIT HIGH SCHOOL MUSIC LIBRARY INSTALLATION

Shelving sawed and finished and percussion cabinet fabricated at TechShop in Allen Park, Michigan.

08

built-in
shelves

40

linear feet each of angle iron and
steel tubing for cabinet frame

18

sheets $\frac{3}{4}$ -inch
birch plywood

Five days to build and install, by seven makers working in shifts.

East Detroit switched its name to Eastpointe in 1992, trying to escape the stigma of the declining city and gain from the association with nearby Grosse Pointe Shores, the little town on Lake St. Clair with marinas for its wealthy residents' big boats. But the new name didn't immediately transform Eastpointe, now one of the most impoverished towns in America. East Detroit High School also has suffered as part of a school district whose budget recently shrank by \$5.6 million in a single year. The cuts hit the high school hard, but music teacher Joe Chouinard felt he had to find a way to help his program. The marching, jazz, and concert bands had won dozens of awards since the school opened in the early 1920s—and had amassed more than 1,000 sets of sheet music. The valuable collection was randomly stacked in a cramped back room.

Chouinard turned to DonorsChoose.org, posting a request for funds to create a music library. "Not only will this allow students to explore more music, but we can also teach the students proper care for these materials and develop their organizational skills as well as their management skills," Chouinard wrote.

In March, with the donation deadline approaching, the project was \$3,191 short of its goal. Popular Mechanics contacted Chouinard, offering help. He laughed incredulously and said, "You're kidding." When he found out we were serious, he quickly asked whether we might also arrange to have a new percussion cabinet made for the students,

The final coat of acrylic had barely finished curing when students from the high school helped makers from TechShop Detroit unload the lumber for the music library (above right). The TechShop team transformed the room in a matter of hours.





because the old one was falling apart.

We turned to TechShop for the design and build. Makers at the Detroit location, actually in Allen Park, about twenty miles from the school, reacted swiftly. “Our members are motivated to do projects that are seemingly off-the-wall—meaning, to create things that can’t be bought off the shelf,” says TechShop Detroit manager Will Brick. “Also, this was the first project we did on this scale that was a direct benefit to the community. A bunch of different makers, all with varied backgrounds and skills—it was cool to get them all together to work on this.”

Within five days a team of seven makers had built the shelves and percussion cabinet and installed them at the school, free of charge.



THE *Originals*

How the Shakers,
an eccentric religious
group, created a
lasting maker legacy
in America.

BY FRANCINE MAROUKIAN

A

Although the Shakers, a splinter sect of the Quakers that arrived in America in 1774, may have looked like bucolic believers to the outside world, they were actually a radical social order of celibate, communistic craftspeople—America's original maker community, and one of its oddest. Long before modernists like skyscraper architect Louis Sullivan declared that form follows function, Shakers were crafting everyday objects of startling simplicity and utility. Not because of some cerebral design aesthetic but because design—of a chair, of a cabinet, of a broom handle—was, to them, direct communication with God.

As observers of Christian millennialism, Shakers believed they were living in the thousand-year reign of peace before the world ended. So, accordingly, they set about perfecting their version of heaven on earth. Rejecting ornamentation as a sin of pride, they relied on clean lines and human proportion: monastic yet never stark, rich and warm in hue, graceful in appearance.

Other contemporary craftsmen may have favored imported wood like mahogany, employing ornate carving and veneers, but Shakers forecast the current obsession with local goods by using only woods that were at hand, such as pine, cherry, and maple. Relying on humble materials in honest construction only intensified the organic beauty of their work. Shakers often highlighted the natural wood grain with radiant monochromatic color washes in specific shades set forth by their Millennial Laws—rules instructing how to live, including architectural regulations that unified their nineteen geographically scattered communities. The permissible colors of yellow ochre, rust red, deep green, and lead blue are now considered classics of Americana, the kind of colors you typically find in heritage collections at the paint store.

The Shakers have a credo: "That which has in itself the highest use, possesses the greatest beauty." So they tweaked the squat and straight New England ladder-back chair until it became a statuesque cradle, elongated and slightly angled to hold the body in a more relaxed position, with graduating curved back slats to provide maximum comfort no matter the sitting time. These were simple changes, but so mindful of physical comfort that contemporary craftsmen still strive to update that chair today—no improvement needed.

The Shaker chair remains a testament to functional innovation: Button-shaped ball-and-socket tilters allow sitters to rock back while keeping the rear legs flat, and oval-shaped back-post finials make it easier to lift the chairs and hang them on the wall. Hanging was typically done upside down, which prevented dust from collecting on the woven-tape or cane seats, on long wooden peg rails, a Shaker trademark.

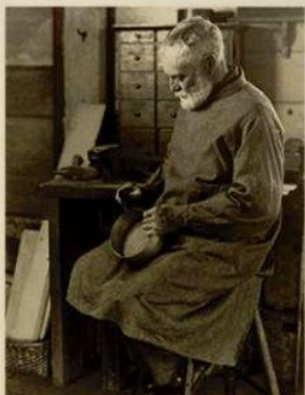
To Shakers, cleanliness had a spiritual dimension, and their preference for wall-mounted furniture and built-in storage (usually with visually pleasing asymmetrical drawer and cupboard arrangements) not only accommodated the needs of communal living but also reduced clutter and made rooms easier to clean. To that end, the Shakers developed a process to compress and stitch broomcorn, a type of sorghum grass, to make the first flat brooms for more efficient sweeping.

For a group that led inwardly focused lives, Shakers never shied away from change. These forefathers of today's DIY movement turned out ingenious gadgets such as metal pen nibs, clothespins, and the apple peeler. They sought time-saving conveniences to lessen daily chores: Communal cooking and laundry inspired a more heat-efficient revolving oven and the first washing mill (machine) to be commercially produced, as well as a method for keeping fabric waterproof and wrinkle-free, achieved by heat-applying a zinc chloride solution.

The list goes on—they were irrepressible inventors. Working together in utopian gender and economic equality, Shakers influenced the world far beyond their own communities: During a time when women had zero presence in the workplace, Shaker scholars credit Sister Tabitha Babbitt with the 1810 invention of the circular saw, inspired by her spinning wheel. Shakers also made a lasting contribution to American horticulture by originating the concept of selling vegetable seeds in small printed-paper envelopes, the prototype for the modern seed pack.

The most enduring evidence of the Shakers' visionary simplicity is the iconic oval-shaped box: a pine disc top and bottom with a side strip of maple (soaked in water and bent to form) held together by swallowtail joints (allowing the wood to expand with humidity) and rustproof copper tacks. Unlike a round shape, the oval took up less shelf space and put less stress on the wood—modest, practical, elegant.

Many modern designers have espoused Shaker design philosophies, including the Arts and Crafts style of Gustav Stickley and the open, streamlined rooms of Frank Lloyd Wright's Prairie School. Meanwhile, home-decor catalogs hawk "Shaker-style" coffee tables, pieces of furniture whose social function and center room placement would have baffled them. But despite all the emulation and knock-offs, the permanent value of the Shakers' maker legacy may be this fundamental truth: In the right hands, craft will be art.





Make your very own Shaker-inspired wall cabinet using our exclusive plans available for free online. It's a classic design and perfect for the intermediate woodworker. Just visit popularmechanics.com/shaker-cabinet-plans to download the free instructions and start making your Shaker cabinet today.



Contributing editor and fine woodworker Richard Romanski in his studio, a former church built in 1875. His exclusive custom workbench project begins on page 99.

THE ULTIMATE WORKSHOP

A great shop is both functional and personal, a creative space packed with tools. In this definitive guide, you'll find advice on what those tools should be, where they ought to go, and what you can do with them. Whether your workshop is a renovated historic church (like this one) or a corner of the garage, we show you how to create a space that will allow you to make just about anything.

The Church AN INTRODUCTION

I WASN'T LOOKING for a church. It just came into my path. I think it was 1978. Could've been '79. The door hadn't been opened since the mid-sixties, but when I first saw it, it knocked my socks off. I said, why not? I could make use of this place. Sure!

The building was what you might call exposed to the elements, but the interior was intact and the structure was sound. The pews remained, so you had a sense of what it felt like in that congregation. It was just this vast space, a structure that still retained its history, so that when you walked through the doors you knew there had been some life in this space, and that things happened here. I just had to figure out how to make it work for me.

That's the real and only question for any work space. How are you going

to make it work for you? And all the questions that go with that: Is there enough light? Is there *natural* light? Is there air? If there's not, you have to say, Huh, how am I going to make this work? That goes for a huge church or an eight-foot corner of the garage.

The interior grew with time. I added partitions based on function and need. Creating smaller spaces allows you to organize. That bigger space might be for larger, basic tools—the band saw, table saw, jointer, the radial arm saw, the wood lathe. The smaller workbench space is where the hand tools are, maybe off to the side or around the periphery. There is economy in maintaining a space, because when you have a smaller space you can control the light, you can control the heat, the air.

I've never really had a master plan. You have to live with a space to learn how to use it. It's evolved. I've evolved.

Let's say you're doing a lot of sanding. You're beyond hand sanding—you've bought a disc sander, then you've got a wide belt sander, then

THE SHOP RULES

A tool is only as good as its blade or bit.

Drywall screws are for construction sites.

Always mark the scrap



a pneumatic drum sander. If you have one on one shelf and one on a table across the room, it doesn't make sense. You want to group them to control the dust. So you create that place within the larger environment, keeping the dust away from, say, shelves where you store a lot of small parts or the table where you apply finishes. Maybe you wheel your sanding equipment around on a cart. It may not end up where you thought it would work for you. You customize the room to what you like to do and how you like to do it. There are no rules.

Look for hidden storage. Use every nook. I have a wall of shelves where I keep handheld power tools. Rather than build the shelves out from a flat wall, I took advantage of the depth of the wall and created simple inset shelves. As time goes on and you gather more, you might need more shelves. But the key is, they have a home. Organization is quieting. When things are piled in a corner and don't get looked at, that's disrupting. You look at that corner and think, Oh my God, when am I going to get to that thing? However big or small your shop might be, it has to be a place that, when you walk away at the end of the night, you know it's okay. And when you come back the next day or the next weekend, there's a sense of order.

I don't think I ever lose sight of the beauty of this place, the magic. I can be here and just see the light coming through that window at a certain time of the year, a certain time of the day, the light is filtered by these particles in the air, and there's some phenomenon that happens. No matter what you're doing—and it could be really important—you step back. You pause. You're in this big space or this little space, and you're all by yourself. And you can create.

Because that's the point, isn't it? That's why I have such respect for this space, the routines and patterns of it. My vocation, what I do, is solving problems. That's what design is. And I feel that when I'm out here, I can solve any problem in the world. — RICHARD ROMANSKI

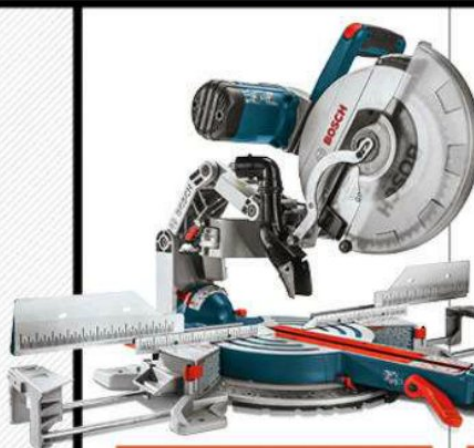
Maker 04
Fact 05

2014

The year TechShop debuted its first mobile maker trailer, a massive, convertible rig equipped with 3D printers, laser cutters, hand tools, and laptops. The plan is to eventually send the traveling shops to middle and high schools in every city that contains a TechShop facility (eight so far, with two more on the way).

THE CORE

The essentials of a well-equipped shop, and three options for each.



MITER SAW



TABLE SAW

MUST HAVE

Crosscuts construction lumber, moldings, or wood for furniture. Put a specialized blade on it and it also cuts plastic pipe and copper tube.

\$70

Craftsman 1725CMSW
7¼-in. compound miter saw
7 amps

Maximum Capacity

- Straight crosscut, no bevel: 2 x 4 in.
- 45-degree miter, no bevel: 2 x 2½ in.

\$200

Makita LS1040
10-in. compound miter saw
15 amps

Maximum Capacity

- Straight crosscut, no bevel: 2¾ x 5½ in.
- 45-degree miter, no bevel: 1½ x 3½ in.

\$650

Bosch GCM12SD
12-in. dual-bevel glide miter saw
15 amps

Maximum Capacity

- Straight crosscut, no bevel: 4 x 14 in.
- 45-degree miter, no bevel: 4 x 14 in.

In basements, garages, and professional shops alike, rips and crosscuts lumber and shapes parts for woodworking joints.

\$130

Ryobi RTS10
10-in. table saw
15 amps

Maximum Capacity

- Depth of cut at 90 degrees: 3 in.
- Depth of cut at 45 degrees: 2½ in.
- Rip: 12 in., right of blade

\$210

Craftsman JT2504RC
10-in. table saw
15 amps

Maximum Capacity

- Depth of cut at 90 degrees: 3 in.
- Depth of cut at 45 degrees: 2½ in.
- Rip: 24 in., right of blade

\$1,600

SawStop CNS175-SFA30
10-in. table saw (with blade-stop safety feature)
14 amps

Maximum Capacity

- Depth of cut at 90 degrees: 3½ in.
- Depth of cut at 45 degrees: 2¼ in.
- Rip: 30 in., right of blade

Phrases You Never Want to Hear in a Man's Workshop

Squinting is the same as wearing safety glasses.

This all-in-one stain and polyurethane is probably just as good.

I threw the owner's manual away years ago. So bulky!

You're telling me I should have measured the opening for the

side of the cut. Mark well: lumber crayon, carpenter's pencil, pencil, marking knife. Accuracy is relative. More clamps. You



DRILL PRESS



PLANER



JOINTER



BAND SAW

► NICE TO HAVE

Makes holes quickly and accurately in wood and metal. Makes you wonder how you ever got on without one.

\$140

Harbor Freight Central Machinery 60237
10-in. benchtop drill press
3.9 amps

- Twelve speeds
- High speed: 2,900 rpm
- Low speed: 300 rpm

\$215

Craftsman ZJQ4116D
12-in. benchtop drill press
4.8 amps

- Twelve speeds
- High speed: 3,065 rpm
- Low speed: 355 rpm

\$350

▲ **Shop Fox W1669**
34-in. benchtop drill press
5 amps

- Five speeds
- High speed: 3,470 rpm
- Low speed: 550 rpm

Controls the thickness of solid lumber. With some finesse and a few tricks, also flattens stock.

\$280

Harbor Freight Central Machinery 95082
Two-knife thickness planer
2.5 amps

- Maximum Capacity**
- Width: 12 in.
 - Height: 4½ in.
 - Depth of cut: ¾ in.

\$350

Delta 22-555
Two-knife thickness planer
15 amps

- Maximum Capacity**
- Width: 13 in.
 - Height: 6 in.
 - Depth of cut: ¾ in.

\$600

▲ **DeWalt DW735**
Three-knife thickness planer
15 amps

- Maximum Capacity**
- Width: 13 in.
 - Height: 6 in.
 - Depth of cut: ½ in.

Flattens a wood surface that becomes a reference plane or an edge to be glued to another. Or it yields a surface that simply looks nicer without saw marks.

\$300

Shop Fox W1829
6-in. benchtop jointer
12 amps, 1½ hp

- Maximum Capacity**
- Depth of cut: ½ in.
 - Cuts per minute: 20,000
 - Knives: two

\$550

Ridgid JP0610
6½-in. benchtop jointer
6 amps, 1 hp

- Maximum Capacity**
- Depth of cut: ½ in.
 - Cuts per minute: 15,000
 - Knives: three

\$1,000

▲ **Jet JJ-6CSDX**
6-in. jointer
13 amps, 1 hp

- Maximum Capacity**
- Depth of cut: ½ in.
 - Cuts per minute: 14,400
 - Knives: three

Cuts curves and also resaws (cuts wood into thinner sections while wasting less wood than thickness planing).

\$220

Craftsman 21400
10-in. band saw
⅓ hp

- Maximum Capacity**
- Width: 9½ in.
 - Height: 4½ in.

\$360

Jet JWBS-100S
10-in. band saw
½ hp

- Maximum Capacity**
- Width: 9½ in.
 - Height: 4½ in.

\$730

▲ **Delta 28-400**
14-in. band saw
1 hp

- Maximum Capacity**
- Width: 13½ in.
 - Height: 6 in.

door before we built this part?

I'm pretty sure the order doesn't matter on the distributor.

Don't waste your time. I already measured that.

Golly, that saw is waaaay too loud.

Spark plugs aren't supposed to be easy to screw in. Just force it. It's fine.

You got to smell this glue!

Epoxy can't be that hard to get off.

Why wouldn't a belt sander work on a bunion?

Those were my good decoupage scissors!

Oh, here it is: The instructions say we should open the

windows... two hours ago.

Pilot holes are for sissies. You don't need a mask, sun-

glasses work just as well for welding. Really.

Please don't tell me we missed Ellen.

need at least one square that has machinist-level accuracy.

More sawhorses.

Always, always safety glasses.

Useful storage con-

How to Decorate Your Workshop

When in doubt: pegboard.

If you choose to put up old license plates, they should be from cars you have owned, not things you found on eBay.

Wall calendars should consist of cars, models, models on cars, or model cars.

Nudity is at the discretion of the shop owner. (To be clear, we're referring to nudity in calendars or posters. Your own nudity would just be dangerous.)

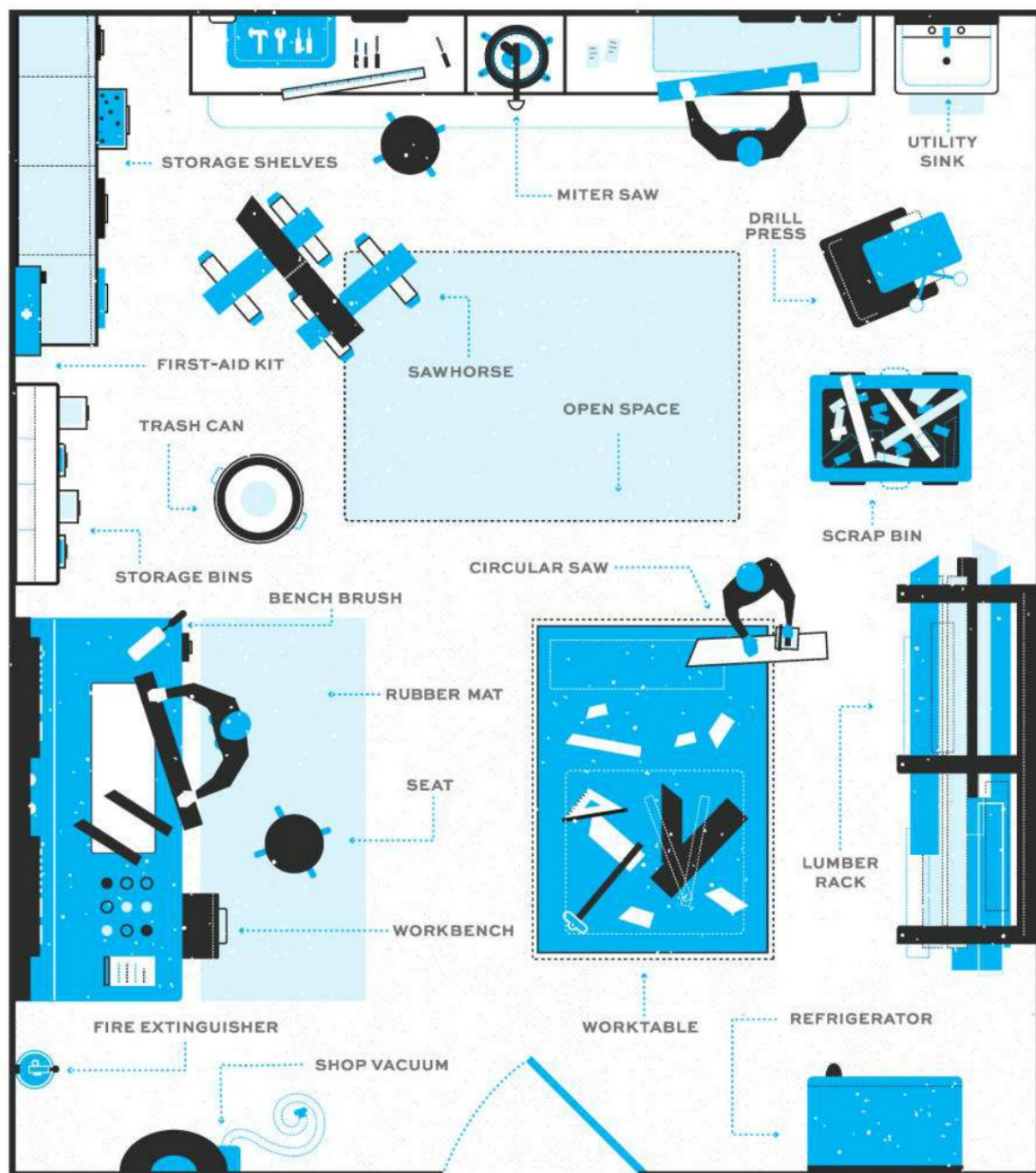
Do you have a high school banner? Put it up.

No TV. But you will need a radio—preferably something analog, with a long, slightly bent telescoping antenna.

For \$10 to \$20 you can find great tin gas-station decals of old Esso or Gulf signs at automobilia.usa.com.

You can never go wrong with more lighting.

Hang a set of labeled bathroom keys. Not because you'll use them, but because you are witty and fun.



The Portable Shop

The Lotus Elan and the Black & Decker Workmate have one thing in common: Both were designed by Ronald Hickman, a South African who left his native country to design cars in England. He was also an avid tinkerer and an amateur builder. While working on a DIY project at home in 1961, he was sawing a piece of lumber on an expensive chair and sawed into

tainers: coffee cans, Mason jars, peanut butter jars, apple crates, shoe boxes, cigar boxes, Altoids tins. No shop is complete without

THE FLOOR PLAN: A WORKABLE MODEL

A man must make his workshop his own, but there are guidelines.

Store lumber, metal, pipe, and all raw materials as close to the entry point as possible.

Make provision for scrap storage and trash. Use 3-mil contractor-grade trash bags for storing sharp and bulky debris. Build a box from ¾-in. plywood mounted on caster wheels for storing and moving large and heavy amounts of scrap.

Open floor space allows you to break down material with a circular saw.

Benches can be mobile or secured to a wall.

Height: For traditional hand-tool

woodworking, 32 to 34 inches. For light metalworking and some light woodworking, 36 to 40 inches. For model building and other work while sitting, 29 inches (desk-top).

Lighting: T8 fluorescent fixtures spaced depending on bulb length, reflector, and lens type. Articulating worklight by bench for detailed work.

Paint ceiling white, walls a light color to scatter light.

Put lighting on one branch circuit. Power-tool outlets go on a separate circuit. If you trip the circuit breaker with a power tool, you

don't also knock out the lights.

Bin storage for fasteners, wire connectors, small plumbing parts, miscellaneous hardware.

Shelves for power tools in existing plastic cases or in shop-made plywood containers.

Flooring: On bare concrete, use clear sealer or two-part epoxy floor coating to improve traction and light reflection, and to make spills easier to clean.

Rubber mat by workbench improves traction, reduces fatigue, prevents damage to

dropped tools. Snap-together modular flooring such as TechFloor improves traction, dampens noise, prevents damage to dropped items.

Locate miter saw with clear access on left and right.

Adjacent work surfaces are flush to miter saw table.

Magnetic bar above workbench holds tools of all different shapes, sizes.

Hang bench brush near bench to sweep off directly into trash can. Or use 2½-gallon wall-mount wet-dry shop vacuum.

Refrigerator. Beer.

its leg. Most people might have purchased a sawhorse at that point. Not Hickman. Hickman set out to design and build a small, portable workbench. The idea he came up with, to solve a relatively simple problem with a complex device, is a classic example of what makes an inventor. Most fail in their attempt, but some succeed, and civilization moves steadily forward.

After a lot of experimenting, Hickman arrived at a working design that was part bench, part vise, and part sawhorse. Black & Decker bought the rights to produce the thing and brought it to North America in

1975. About five years later I saw one for the first time when the owner of a construction company I was working for pulled one out of his truck. It was then and remains a marvel of industrial design. You can set it up in seconds. It stores flat. And it's light. The 425 Workmate, the current version, weighs in at twenty-six pounds and is rated to support 550. It sells for about a hundred bucks. Less robust models cost as little as thirty. You can use it to hold a bike you're repairing, clamp construction lumber to build a shed, and for about a million other things.

If success is measured in numbers, the

Workmate became a blockbuster. Black & Decker estimates that 30 million of them have been sold worldwide.

I've been an editor at Popular Mechanics for twenty-six years. I've purchased two Workmates for the magazine in that time. We're always driving around doing some project or another, and they are indispensable. But sometimes I have the urge to work without it. Why? Because when you don't have what you need, you're forced to improvise, and only improvisation could lead to an invention like the Black & Decker Workmate. Hey, you never know. — ROY BERENDSOHN

The Popular Mechanics Workshop Reference:

Issue/Not an Issue

	ISSUE	NOT AN ISSUE
Can't find hammer	X	
Spilled paint		X
Hammered your thumb	X	
Cordless drill is dead		X
Dinged your workbench		X
Stripped a screw		X
Lost track of time		X
Lost track of time and missed brunch with your wife's friend		X
Got a quick shock		X
Mixed cleaning products	X	
The shop vac is full		X
Spilled oil	X	
Cut finger (shallow)		X
Cut finger (deep)	X	
Cut finger (off)	X	
Learned the meaning of arc flash	X	
Cut too short	X	
Cut too long		X
The kids came in		X
Forgot to buy post-project beer		X

a source of music. // There's no excuse for dull tools. // And so, must-haves: sharpening stones, bench grinder, grinding-wheel dressing

SOME THOUGHTS ON

Dust

Sawdust, plaster dust, drywall dust, any kind of dust—none of it is good for your lungs, your floor, your tools, or your desire not to start a fire. Getting rid of it is both essential and easy.

RULE 1: Catch dust while it's airborne.

► Because dust is first suspended in the air, it makes sense to use air to transport it for disposal. A wet-dry shop vacuum will take care of most of it. For example, hook a Dust Deputy cyclone collector (\$100, oneida-air.com) to work with any vac and you create an efficient two-stage dust collector that mimics what industrial wood shops use. The funnel-shaped Deputy swirls wood chips and dust like water going down the drain, collecting them in the bottom of the tank—the first stage. The remaining fine particles continue to the shop vacuum and its air filter.

RULE 2: Be inventive.

► Poke around woodworking-supply websites and you see all kinds of adapters, hoses, and shrouds to hook up to your equipment. That's how we found the dust-trapping Chop-Shop Saw Hood from FastCap (\$142, fastcap.com). Sawdust flies against the slippery back of the hood and falls by gravity into a spare cardboard box. Mission accomplished.

If you prefer a home-brewed solution, make a hood out of plywood, particleboard, or sheet metal. Lumberyards did this all the time at the height of the radial-arm-saw era.

RULE 3: Sweep up the rest.

► Don't waste your time with cheapo brooms and a flimsy dustpan. Buy a contractor-grade push broom, a commercial-duty bench brush, and a big aluminum or steel dustpan.



THE NEW ESSENTIALS

Most of the tools you need are the same stuff your grandfather needed. And yet innovation persists. Your grandfather would have *loved* a cordless circular saw.

01

Craftsman's **Mach Series wrench** is forged from a block of steel for the ultimate in strength and durability. To adjust its jaws, just slide the thumb button. The 8-inch size costs \$40, which is such a good deal you'll almost feel bad.

02

We've seen the future of handheld cordless tools, and it's brushless. The motor on **Makita's 18-volt Xvj02Z cordless jig saw** (\$290, tool only) runs practically forever and optimizes speed and torque for cutting metal, wood, and composites.

03

The classic 6-foot folding ruler gets an update with the Swiss-made **Rhino Ruler** (\$15): wear-resistant fiberglass-reinforced polyamide plastic with engraved (not painted) graduations on both sides. Its spring-loaded joints are tough and fold with a precise snap. Nice ruler.

04

Next time your cousin-in-law needs to borrow tools, pack them in the **FatMax 4-in-1 Mobile Work Station** (\$100). It combines a deep bin, a small-parts bin with removable dividers, and a toolbox with lift-out tray in a clever hand-truck design, which makes it easy to take home the twelve-pack he owes you.

05

Bosch is known for the power and precision of its **portable planers**, and with the introduction of the PL1632 (\$120), you are again reminded why. For power it's got a 6.5-amp motor. For precision its cutting tool adjusts in 1/64-inch increments. Which is handy, because you can't add the wood back.

06

Machine-tool precision meets woodworking with the **Woodpeckers Precision Aluminum Square** (\$100). It's CNC-milled from a block of aluminum to plus or minus 0.001 inch along its edges. A fence holds the square itself to the surface, requiring only gentle pressure from you to hold it against the edge.

07

The **Kreg Jig K5** (\$140) is a self-contained pocket-screw fastening center. Its ratchet clamp quickly grips and releases any wood, and drill and drive bits and screws are stored in two compartments.

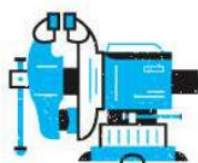
08

Milwaukee throws down the gauntlet with its **M18 7 1/4-inch circular saw** (\$230). Weighing just 9 pounds (with battery), the 18-volt tool is lighter and faster than corded saws, the company says. Our impression after a test drive: Yep. It's fast and light. And its magnesium shoe is as slippery as a piece of cookware.

tool. The pocket screw is the greatest of all screws. Think. Measure. Mark. Think. Cut. In that order. Just buy a whole bunch of

KNOW YOUR VISES

You can't do good work without a good vise.



FOR MOST JOBS

\$278

The head on the Yost 750-DI rotates 360 degrees, with stops every 30 degrees. When combined with its swivel base and three types of jaws (parallel, V, and pipe), it holds anything.

JAW OPENING: 5 inches
YOSTVISES.COM



FOR ODD-SHAPED THINGS

\$200

Lash a chain vise around an object and tighten with a couple of cranks. The Ridgid BC410P is designed for pipe but also secures objects such as andirons and taxidermy.

JAW OPENING: Pipe diameter up to 8 inches
RIDGID.COM

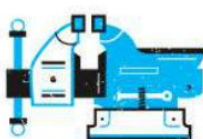


FOR CONSTRUCTION AND REMODELING

\$110

Screw BenchJaws to a bench or any ridged surface. They clamp with a foot-activated lever, leaving your hands free, and support 220 pounds with up to a ton of clamping force.

JAW OPENING: 16 inches (with accessory jaw, 24 inches)
ROCKWELLTOOLS.COM



FOR BASHING METAL

\$465

Equal parts anvil and vise, the Yost FSV-7 is the last word in strength, impact resistance, and durability. It's not built of ductile iron (strong) or even cast steel (stronger) but forged steel (just ridiculous), right down to its three-hole swiveling base.

JAW OPENING: 7 inches
YOSTVISES.COM



FOR PORTABILITY

\$77

You don't always have access to a workbench to hold a vise. Sometimes a sawhorse or even a piece of lumber has to stand in. But clamp the Yost Model 250 vise to any surface up to 1½ inches thick and you've got yourself a setup.

JAW OPENING: 2¼ inches
YOSTVISES.COM

Maker 05
Fact

05

Launched in Pittsburgh in 2011, a non-profit called Operation Valor Arts offers veterans instruction in skills like carpentry, welding, and design and photography. The veterans are then paid to construct memorial sculptures and gardens to honor fallen colleagues.



A Space Perfected

Nobody can define the perfect workshop for anybody else. That space is a fingerprint, as personal as musical taste. Put me in a workshop that looks the way jazz sounds and I'd find the first tool that would allow me to cut out my eyes. There aren't even any universal adjectives that we could apply: "Clean" might seem like an obvious one, but I know good carpenters who thrive in clutter. We could agree that certain tools are a must—a table saw, for instance—but then we'd diverge, because saws are like golf clubs, like steering wheels. They're instruments that fit our hands, and no two feel alike.

The best single workshop I've seen (if only on video) is Nick Offerman's temple to sawdust. He's the actor who played Ron Swanson on *Parks and Recreation*, and he's a woodworker of considerable grace. I'm sure his workshop, in the flesh, is some rare combination of financial and technical wherewithal, the product of a man who has money and knows how to use the precision machines he buys with it. I'm just as sure I could find a different woodworker who would walk into Offerman's workshop and sniff out a hundred faults. That guy would be a jealous dick, but he's out there.

So where does that leave us? Even if we don't agree on what blades are necessary, I can't think of a single craftsman who wouldn't want those blades to be sharp. At least one surface that is clear and level enough to split atoms. Light that is warm and raises the finest grain.

Mostly, though, I think the perfect workshop comes down to something more ephemeral, that same elusive sensation that draws any of us to a particular hammer or paintbrush. The perfect workshop is, in its own way, a tool rather than a collection of them, only it does its work on us. It makes us feel capable, and it makes us feel content, and it makes us feel as though we can make every last thing we might dream to make. —CHRIS JONES

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Like a picked flower cut from the source, we gradually wilt physically and mentally and become vulnerable to a host of degenerative diseases, that we simply weren't susceptible to in our early adult years.

Modern medical science now regards aging as a disease that is treatable and preventable and that "aging", the disease, is actually a compilation of various diseases and pathologies, from everything, like a rise in blood glucose and pressure to diabetes, skin wrinkling and so on. All of these aging symptoms can be stopped and rolled back by maintaining Growth Hormone levels in

the blood at the same levels HGH existed in the blood when we were 25 years old.

There is a receptor site in almost every cell in the human body for HGH, so its regenerative and healing effects are very comprehensive.

Growth Hormone first synthesized in 1985 under the Reagan Orphan drug act, to treat dwarfism, was quickly recognized to stop aging in its tracks and reverse it to a remarkable degree. Since then, only the lucky and the rich have had access to it at the cost of \$10,000 US per year.

The next big breakthrough was to come in 1997 when a group of doctors and scientists, developed an all-natural source product which would cause your own natural HGH to be released again and do all the remarkable things it did for you in your 20's. Now available to every adult for about the price of a coffee and donut a day.



GHR now available in America, just in time for the aging Baby Boomers and everyone else from age 30 to 90 who doesn't want to age rapidly but would rather stay young, beautiful and healthy all of the time.

The new HGH releasers are winning converts from the synthetic HGH users as well, since GHR is just as effective, is oral instead of self-injectable and is very affordable.

GHR is a natural releaser, has no known side effects, unlike the synthetic version and has no known drug interactions. Progressive doctors admit that this is the direction medicine is seeking to go, to get the body to heal itself instead of employing drugs. GHR is truly a revolutionary paradigm shift in medicine and, like any modern leap frog advance, many others will be left in the dust holding their limited, or useless drugs and remedies.

It is now thought that HGH is so comprehensive in its healing and regenerative powers that it is today, where the computer industry was twenty years ago, that it will displace so many prescription and non-prescription drugs and health remedies that it is staggering to think of.

The president of BIE Health Products stated in a recent interview, I've been waiting for these products since the 70's. We knew they would come, if only we could stay healthy and live long enough to see them! If you want to stay on top of your game, physically and mentally as you age, this product is a boon, especially for the highly skilled professionals who have made large investments in their education, and experience. Also with the failure of Congress to honor our seniors with pharmaceutical coverage policy, it's more important than ever to take pro-active steps to safeguard your health. Continued use of GHR will make a radical difference in your health, HGH is particularly helpful to the elderly who, given a choice, would rather stay independent in their own home, strong, healthy and alert enough to manage their own affairs, exercise and stay involved in their communities. Frank, age 85, walks two miles a day, plays golf, belongs to a dance club for seniors, had a girl friend again and doesn't need Viagra, passed his drivers test and is hardly ever home when we call - GHR delivers.

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A WORKBENCH FOR ALL TIME

Smart design. Solid construction. On this bench, you can build anything.

BY RICHARD ROMANSKI

A workbench can be utilitarian and thrown together or it can be beautifully handcrafted. Both can function about the same, but it's more likely the latter example will be a pleasure to use and to own.

When Popular Mechanics asked me to design and build a workbench as a project and as a centerpiece of its New York workshop and studio, I knew the bench had to reflect the brand and its no-nonsense heritage. I wanted it to have crisp lines and pleasing proportions. But most important, it had to be functional. It would be a bonus if, somehow, the bench reflected the magazine's association with house construction. Popular Mechanics has covered the topic for more than a century, and has published books on building your own house. ➔

So I decided to build the bench out of construction lumber—clear Douglas fir, LVL joists (which are like large sheets of plywood) sawed into narrow strips then glued into a slab, and MDO, a form of plywood with a laminate surface.

The bench is ambitious, but it can be built by a home craftsman who owns a small table saw and a benchtop planer. Here's how to build one for yourself.

MAKE THE BENCHTOP

The bench is not difficult to build, but it requires a methodical construction process. If you follow the procedure carefully, you get a massive top that's flat, square, and needs hardly any cleanup after it's glued together. The top has four rows of bench-dog holes bored into it. Specialized hardware called bench dogs fit into these holes, and when combined with other accessories and our Yost woodworking vise, the benchtop can hold a workpiece of just about any shape or reasonable size.

Making the top begins at the lumberyard. We purchased two LVL joists. These are like massive sheets of plywood. Each measures 1¾ inches x 9½ inches wide by 16 feet long. To make them more manageable we had the lumberyard crosscut them into two 62-inch lengths. The remaining offcut was 68 inches long.

Next I installed a fifty-tooth combination rip-crosscut blade on my table saw. This is the perfect blade for neat ripping operations. The deep gullets at the base of its teeth keep the blade running cool, and this helps prevent burn marks on the lumber.

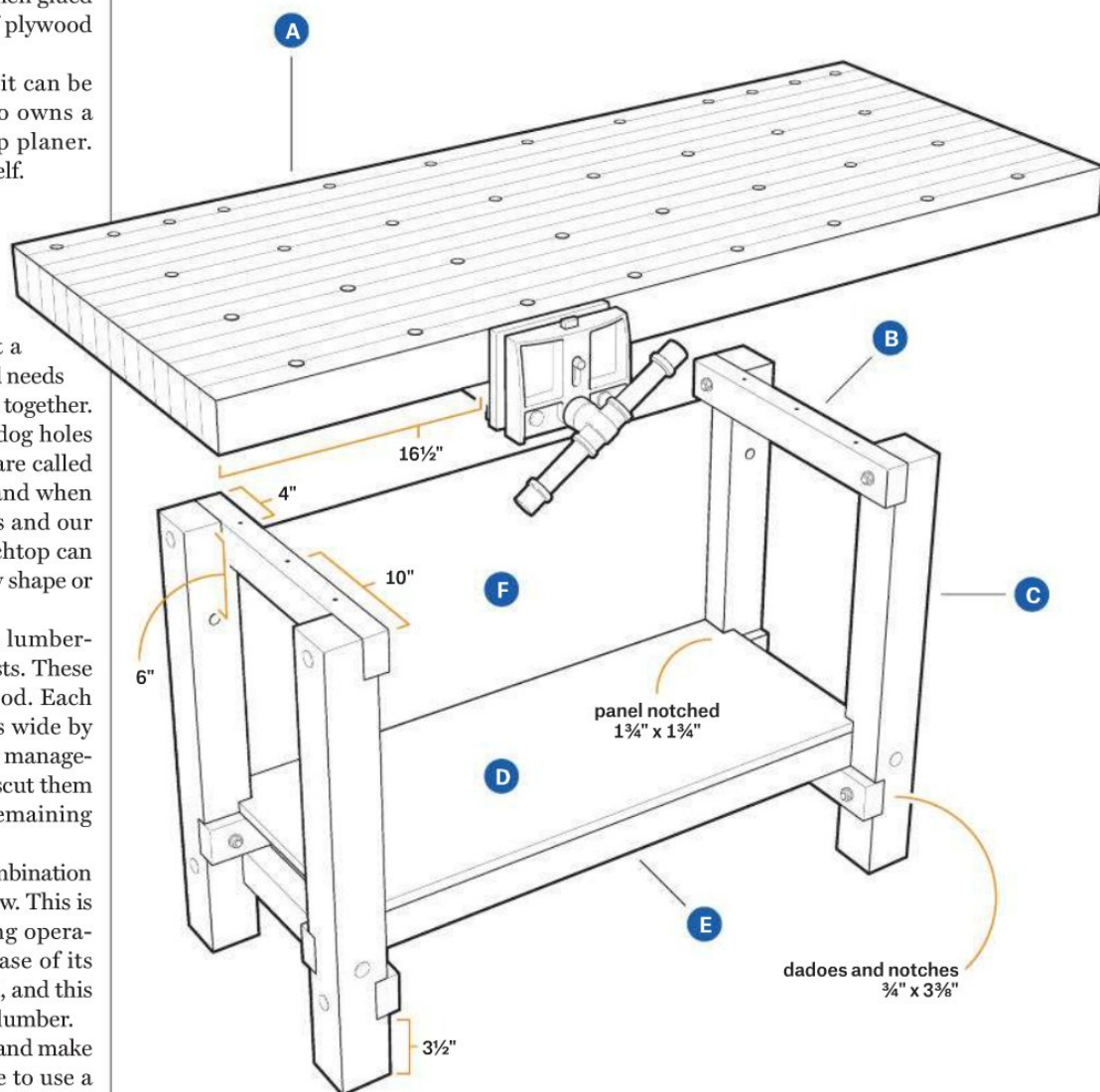
Set the saw fence to 3⅝ inches and make the first ripping pass (1). Be sure to use a push stick as you near the end of the cut. Make one rip pass on each of the six pieces of LVL. Use a woodworking square and a straightedge to check the ripped edge for square and flatness.

Now shut the saw off and reset the fence to 3 inches. Take each of the six pieces that



WORKBENCH

The laminated top is lag-screwed to the base below.



MATERIALS

Key	No.	Size and description
A	1	3" x 23½" x 60" LVL (laminated top)
B	4	1⅝" x 3⅝" x 20¼" Douglas fir (cross supports)
C	4	3⅝" x 3⅝" x 31" Douglas fir (legs)
D	1	¾" x 16" x 41¼" medium density overlay (shelf)
E	2	1⅝" x 3⅝" x 44¾" Douglas fir (long supports)
F	1	¾" x 20½" x 38¾" medium density overlay (back panel)

SHOPPING LIST

2	1¾" x 9½" x 16' LVL RigidLam joist
2	4" x 4" x 8' clear Douglas fir
2	2" x 4" x 8' clear Douglas fir
1	¾" x 4' x 8' medium density overlay panel
12	⅜" x 4½" galvanized carriage bolts, washers, nuts
6	⅜" x 4½" galvanized lag screws
1	Yost 7-inch woodworking vise, model 7WW-CA; Lee Valley & Veritas bench dogs and accessories to suit

Misc.: Watco Danish Oil Finish, wood glue, sandpaper

CONTINUED ON PAGE 105 ➔

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CONTINUED FROM PAGE 100

you ripped, place the freshly sawn edge against the saw fence and feed the piece through the saw again (2). This produces six pieces of LVL with two sawn edges and no factory edge. Why bother? This ripping method eliminates the factory edge and its minor imperfections.

Rip the remaining LVL pieces to 3 inches wide. Always place the freshly sawn edge against the table-saw fence.

When you're done, select the best fourteen 3-inch-wide pieces. Each should have two neatly sawn and perfect edges.

Next, carefully examine the face (the 3-inch width) of each piece and use a block plane to remove any small bumps where two pieces of veneer overlap. Making an extremely light cut, feed each piece through a benchtop planer to produce a consistently flat and straight surface free of the waxy protective coating that's applied to the joist at the mill (3).

After planing, crosscut the pieces on a miter saw using a stop block to produce a consistent length.

Now bring four LVL pieces to a reliably flat work surface and apply glue on the face of each piece using a foam paint roller (4). Clamp the pieces together using the rest of the benchtop pieces as a reference plane and a clamping block. Use a rafter square to ensure that the pieces stay aligned (5), and use cauls (sturdy pieces of lumber that you clamp down across the top of the assembly) to make sure that the assembly stays flat (6). Cover the cauls with wax paper to prevent glue from sticking to them.

When the glue has cured, repeat this procedure to glue the next three pieces of the top (don't glue the first four pieces to the next three pieces). Clamp



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PROJECT



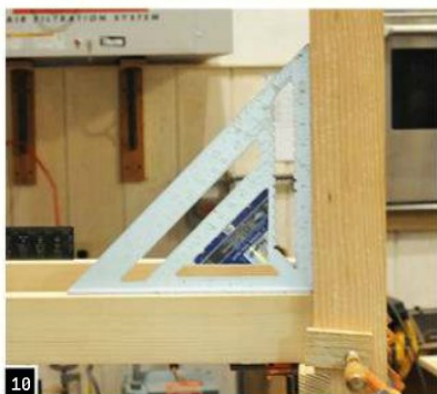
7



8



9



10



11



12



Lee Valley & Veritas makes accessories sized to fit into $\frac{3}{4}$ -inch-diameter holes: bench dogs, cam-lever stops, thin planing stops, horizontal vises, and fast-acting hold-downs that provide vertical clamping pressure (leevalley.com). When paired with a heavy-duty Yost professional vise, there isn't anything this bench won't hold.

this three-piece subassembly between the four-piece assembly on one side and the rest of the loose benchtop pieces on the other side.

Repeat this with the next three LVLs and the remaining four. You should be left with two three-piece assemblies and two four-piece assemblies. If you're tempted to skip this multistep process, don't. It's easier to glue up small assemblies than a large one.

Next, lay the glued-together subassemblies on a flat surface. Measure and mark the centerlines of the holes for the bench dogs based on the diagram on the opposite page. Separate the pieces and continue the reference line for the bench-dog holes down the face of each piece. Install a $\frac{3}{4}$ -inch brad-point bit in the drill press and mark a reference line on its fence to match the center of the bit. Now take each glued-together three-piece and four-piece assembly, align each mark for a bench-dog hole with the one on the fence, and bore the holes in its edge (7).

Complete the top by gluing and clamping the four sections together. After clamping, use a cabinet scraper to remove any hardened globs of glue.

Now flip the top over and mark the outline of the mounting pads for the Yost vise. The benchtop is thicker than the vise is designed for so you need to cut a $\frac{5}{8}$ -inch-deep recess for it. Relative to those lines, clamp a straightedge across the benchtop to guide a plunge router to cut the recess (8).

Sand the benchtop with 100-, 120-, and 150-grit sandpaper, and wipe on a coating of Watco Danish Oil Finish and install the vise.

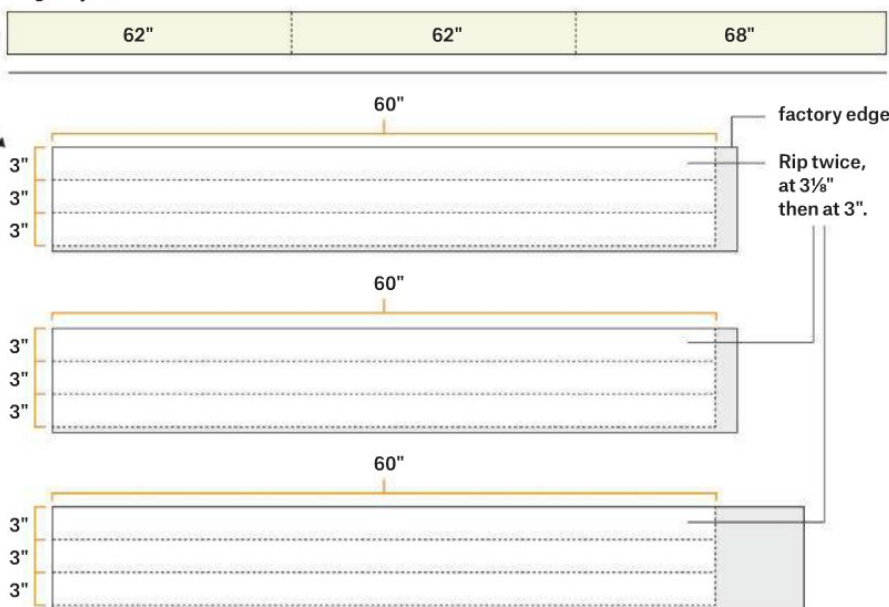
MAKE THE BASE, MOUNT THE TOP

Begin by crosscutting 2 x 4 and 4 x 4 lumber for the base

FROM JOIST TO STRIPS TO TOP

Each LVL joist is cut into three pieces. The pieces are ripped into strips, which are glued together.

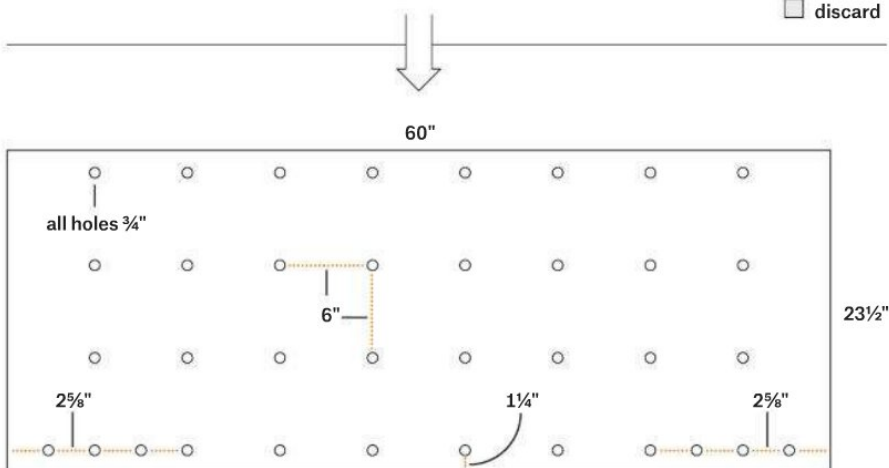
original joist



factory edge

Rip twice,
at 3 1/8"
then at 3".

discard



using a miter saw and stop block. Then feed these shortened sections through the planer to reduce their thickness. Each piece of 4 x 4 is reduced to 3 3/8 inches in both dimensions and the 2 x 4s are reduced to 1 3/8 x 3 3/8 inches.

Install a dado blade in the table saw and use some scraps from the 4 x 4 to test the setup, then cut the dadoes and notches in the bench legs (9).

Our bench was built with a back panel for aesthetic reasons only. It serves no structural purpose. You can omit this feature, but if you decide to use it, then cut a shallow 3/8-inch-deep groove in the legs using a router with a 3/4-inch-diameter bit and a fence.

Next, dry-fit the legs and cross supports

by clamping them together. Use a rafter square to check the assembly (10). With the parts still clamped together, bore the through holes for the carriage bolts.

Sand the legs and cross supports with 100- and 120-grit sandpaper (11). Use a small router and a chamfer bit to ease the corners on the legs and cross supports.

Wipe on a coating of Watco Danish Oil Finish to the legs and cross supports, then bolt the base together. Now mount the top. The benchtop is flush to the outside surface of the base on the back. Center the top on the base left to right, bore 1/4-inch pilot holes through the cross supports and into the top (12). Drive the 3/8-inch lag screws into the top. Now that the bench is complete, build something great.

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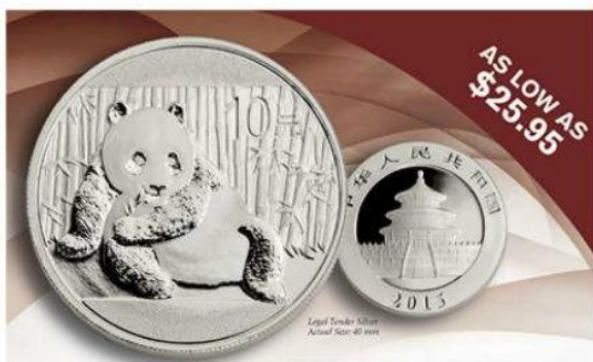
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SNACK-SERVING ROBOT

DESIGNED BY LITTLEBITS

Materials

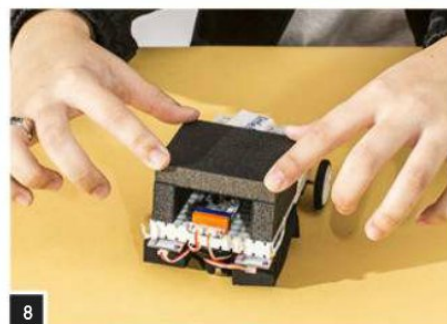
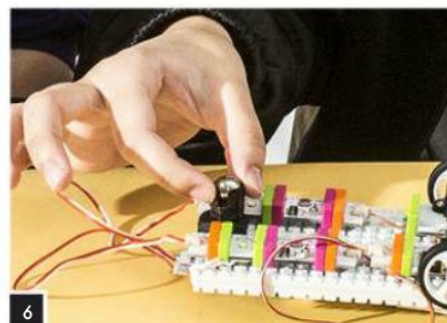
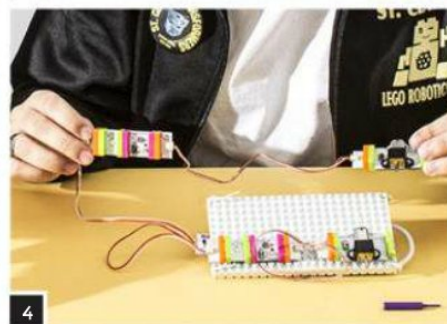
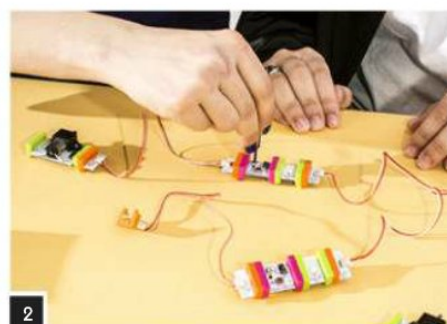
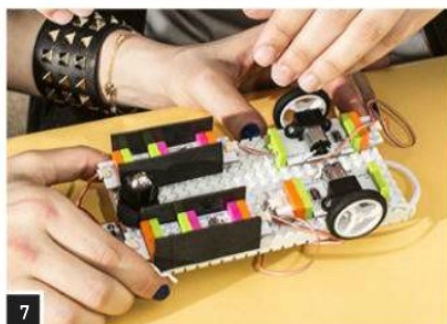
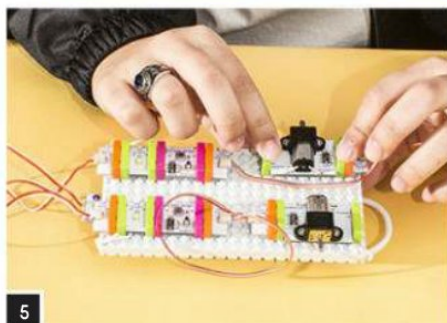
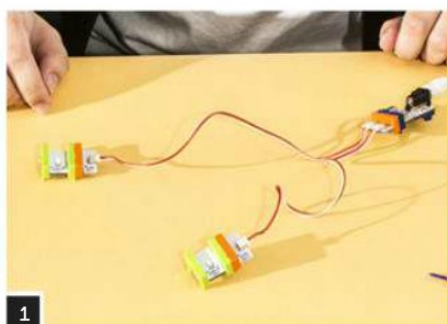
QTY.	DESCRIPTION
1	LittleBits split
2	LittleBits bright LEDs
2	LittleBits DC motors
1	LittleBits screwdriver
1	LittleBits power module
2	LittleBits wires
2	LittleBits mounting boards
2	LittleBits light sensors
1	9-volt battery and littleBits cable
4	Twist ties
1	24" x 36" foam-core board
1	Roll black electrical tape
1	Adhesive foam sheet
1	Lightweight snack bowl
1	Roll double-sided adhesive foam tape
1	Pololu ball caster with 3/4" metal ball (No. 995)
2	7 x 32-mm Pololu wheels (No. 1088)
3	Pieces 1/2" foam board (two each 1" x 2 1/2", one piece 2 1/2" x 2 3/4") to build U-shaped bowl holder

To receive a \$20 discount on parts, use the promotional code **POPMECHSNACK** at <http://littlebits.cc/projects/snack-robot>.

Instructions

● parent only
● parent and kid
● kid only

1. Build a circuit by connecting parts in this order—battery and cable, power, split—then attach one bright LED to each terminus of the split.
2. To each bright LED connect the following units in this order: light sensor, wire, DC motor.
3. Hold the mounting boards back-to-back, line up the holes in each corner, and fasten the boards together using a twist tie threaded through the holes. Lay the boards on the table, and press-fit the power-and-split coupling in the middle of the edge of a short side of the board. Be sure to center the parts on the edge to ensure that your robot will be balanced.
4. Flip the boards over and press-fit the LED/light sensor/wire assemblies into two corners, with the white rectangles protruding from each split at the edge of the shorter side.



5. Align the DC motors with the LED assemblies and press-fit into the same mounting board. Orient the motors in opposite directions, with the axles sticking out from the sides of the board. Along the long sides of the board, the modules should be lined up in this order: split/bright LED/light sensor/wire/DC motor. Use the toggles to set the right motor's direction to LEFT, the left motor's direction to RIGHT. Test the motors to be sure they turn in the same direction. Attach a wheel to each axle.
6. Use the foam tape to stick the ball caster to the board, between the LEDs.
7. Use foam-sheet pieces to build rectangular boxes to act as blinders around each LED and light sensor. Start by putting foam-sheet pieces along the long sides, and then close up the ends

with additional pieces. Use the toggles to set the light sensor to LIGHT mode.

8. Flip the unit. Use foam-board pieces to build the bridge on which the bowl will rest, using double-sided tape to connect the three pieces. Tape the assembly to the board.

Your robot is ready to operate. Use electrical tape to make a zigzag line with oblique angles on the foam-core board. Switch on the power and put the robot on the board, with the caster ball on the tape and the wheels straddling it. To keep the robot on the path, adjust the light sensors by turning the tab marked SENSITIVITY with the screwdriver. When the sensors are held facing an overhead light, the wheels should turn very slowly. This ensures that the sensors respond to the LEDs correctly.





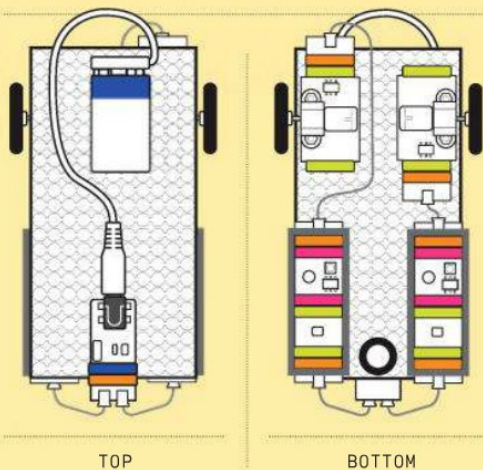
Daniella Gomes, 13, a budding engineer from Staten Island, New York, calls littleBits founder and CEO Ayah Bdeir, left, "super-inspiring."



A SNACK-SERVING ROBOT!

Delivers candy or chips (or fruit) to everyone at the table.

DESIGNED BY LITTLEBITS



TOP

BOTTOM

FOUNDED BY MIT Media Lab alumna Ayah Bdeir in 2011, littleBits has become a force in the world of STEAM education. The company name describes its products: colorful electronics components as easy to assemble as Lego bricks. It's a joy to connect the power modules, motors, sensors, LED lights, and other out-of-the-box parts, creating a single unit that seems to come to life. It's so much fun, in fact, that you wouldn't know you were learning fairly sophisticated lessons in circuitry, automation, and robotics.

Daniella Gomes, 13, studies these things at Saint Clare School in Staten Island, New York, and was on the 2015 regional First Lego League robotics winning team. "I want to be an engineer," she says. "I feel like I can make anything."

And so, with Bdeir's assistance, Gomes built the snack-serving robot. It incorporates six littleBits components, which are sold via the company's website. Two bright LEDs and light sensors rigged to motors keep the robot

Watch a short video on how to make this project at popularmechanics.com/little-bits-project.

Difficulty: EASY REASONABLE HARD
Time: 2 hours **Ages:** 12+

moving along a line of black electrical tape. "The sensors," Bdeir says, "control the robot's speed and direction by regulating the motors."

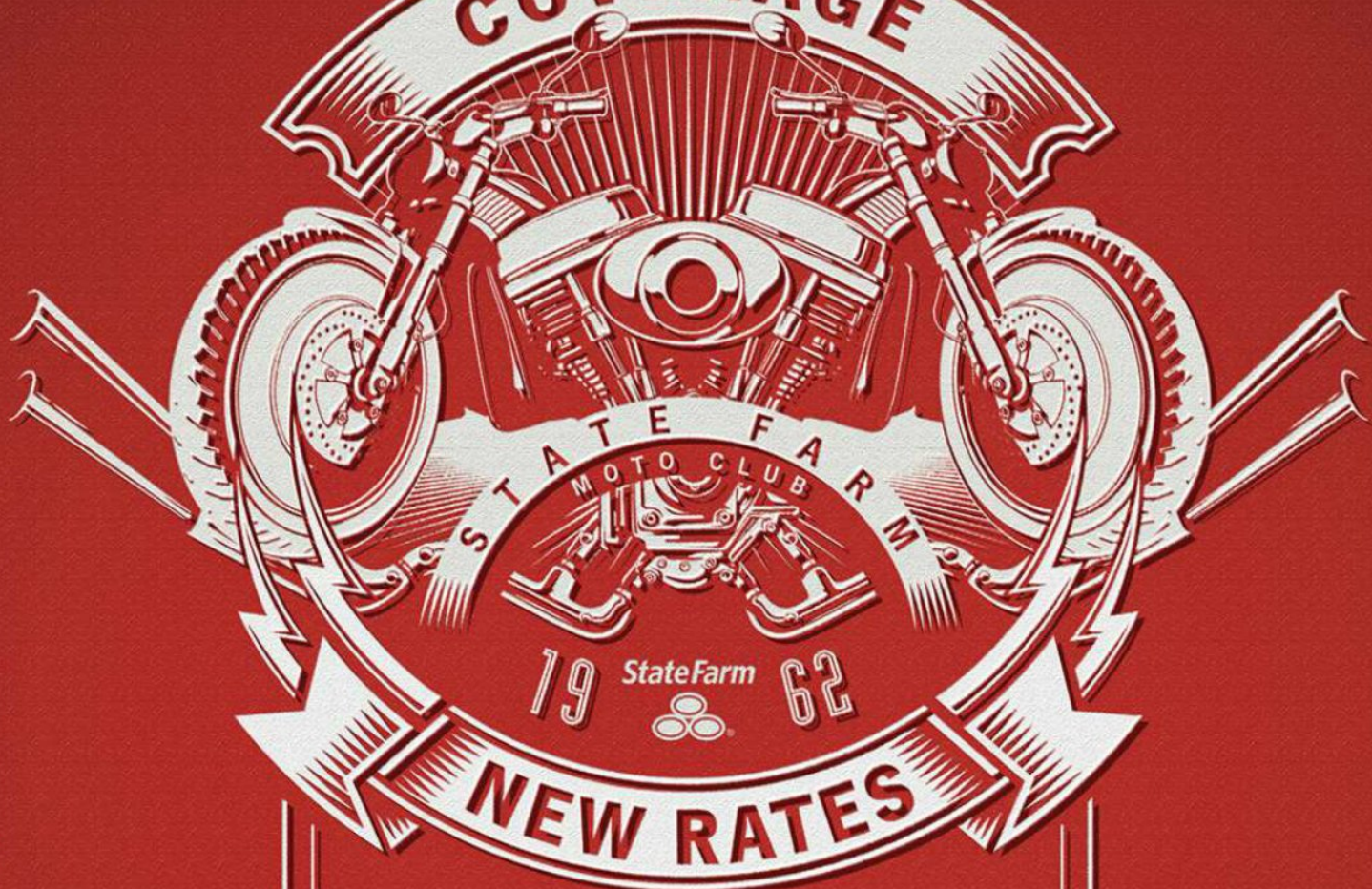
The relative brightness of the light detected by the sensors (low from the dark tape, high from the surrounding area) causes them to make the motors turn fast or slow. The robot veers in the direction of the slower motor, just like

a rowboat turns toward the oar that paddles slower than the other.

Gomes found building the bot straightforward (littleBits snap together with magnets), but calibrating the sensors to keep it on track was tricky. "I usually do that with programming," Gomes says. "Working with the sensors was really cool."

Almost as cool as having a robot deliver candy to you.

LEGENDARY
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